US009282065B2

(12) **United States Patent**
Miki

(10) **Patent No.: US 9,282,065 B2**
(45) **Date of Patent: Mar. 8, 2016**

(54) **RELAY UNIT**

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(73) Assignee: **Oki Electric Industry Co., Ltd.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 223 days.

(21) Appl. No.: **13/605,441**

(22) Filed: **Sep. 6, 2012**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Sep. 30, 2011 (JP) 2011-216493

(51) **Int. Cl.**
H04L 29/14 (2006.01)
H04L 12/939 (2013.01)

(52) **U.S. Cl.**
CPC ***H04L 49/555*** (2013.01); ***H04L 69/40*** (2013.01)

(58) **Field of Classification Search**
CPC H04L 49/555; H04L 69/40
USPC 370/401
See application file for complete search history.

(56) **References Cited**

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Office Action issued by the Korean Patent office on Nov. 25, 2013 with a partial English translation.

* cited by examiner

Primary Examiner — Khaled Kassim
(74) *Attorney, Agent, or Firm* — Rabin & Berdo, P.C.

(57) **ABSTRACT**

A relay unit includes a main-system switch and a sub-system switch that are connected to each other via an inter-system line, that are connected to a main-system line and a sub-system line, and that relays a frame; and control sections that control a relay operation of the main-system switch and the sub-system switch. The control sections store information on a number of connections of relay units and information on a connection priority, and select a control aspect of the relay operation of at least one of the main-system switch and the sub-system switch according to the number of connections and the connection priority.

4 Claims, 58 Drawing Sheets

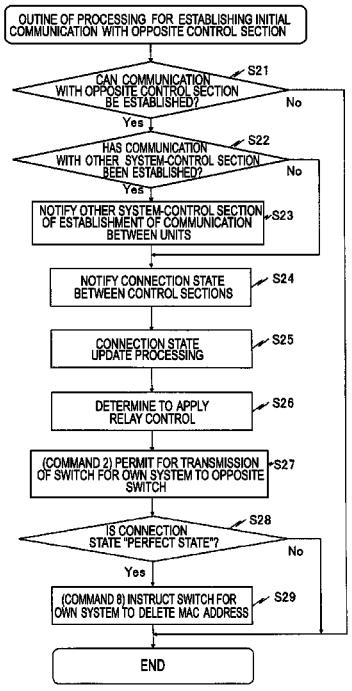


FIG.1

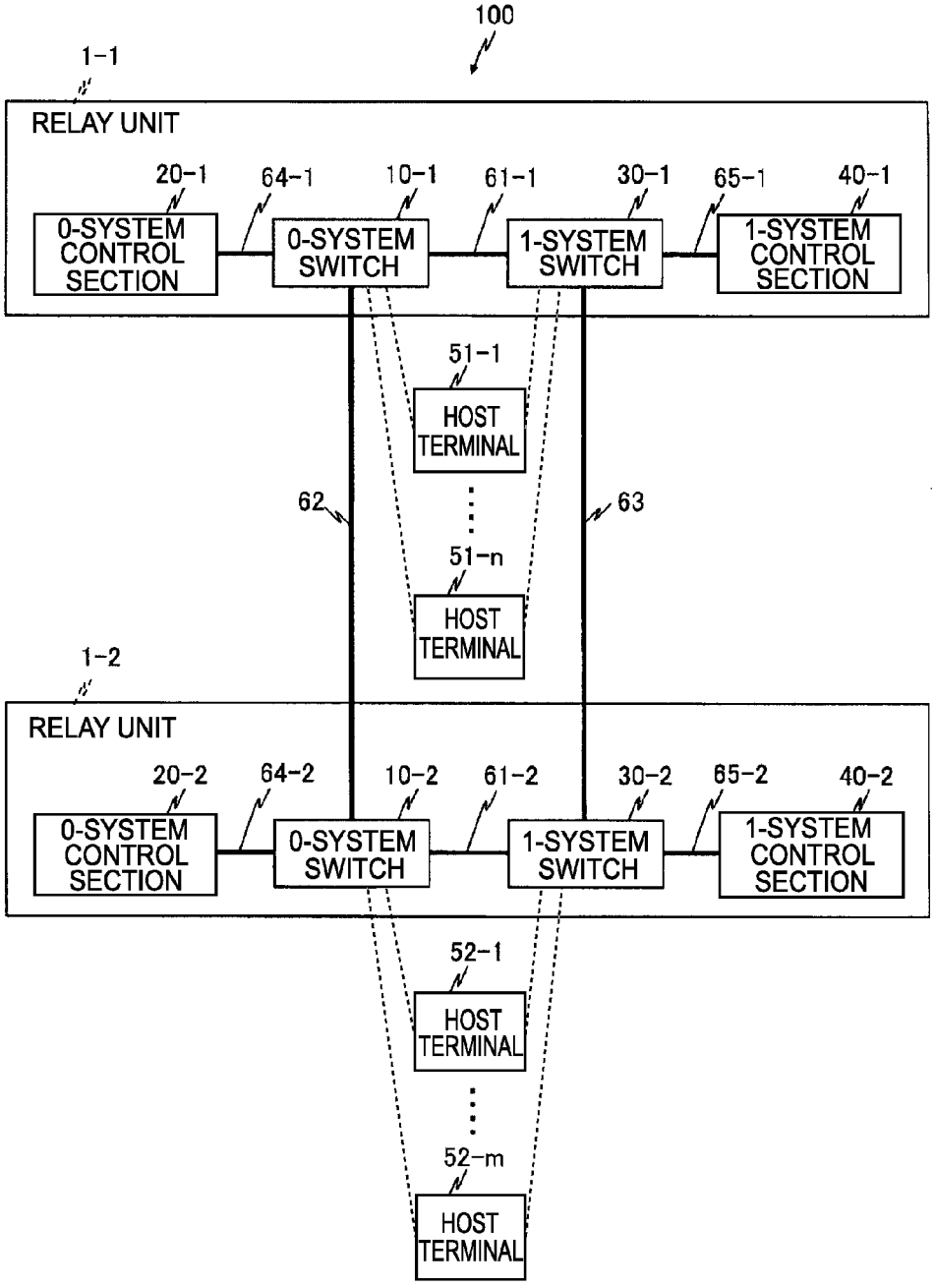

100
1-1
RELAY UNIT
20-1
64-1
10-1
61-1
30-1
65-1
40-1
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
51-1
HOST TERMINAL
62
63
51-n
HOST TERMINAL
1-2
RELAY UNIT
20-2
64-2
10-2
61-2
30-2
65-2
40-2
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
52-1
HOST TERMINAL
52-m
HOST TERMINAL

FIG.2

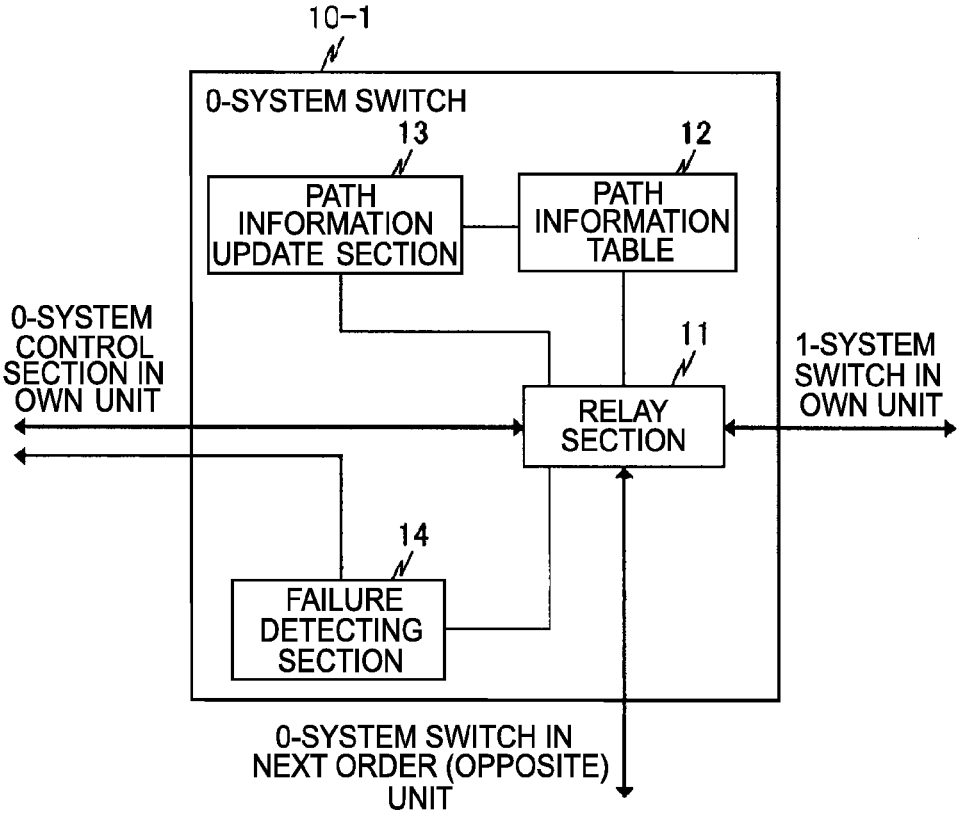


FIG.3

ADDRESS	VIRTUAL GROUP	TRANSMISSION PATH
Aa:bb:cc:dd:ee:ff	A	61-1
11:22:33:44:55:66	A	62
11:22:33:44:55:66	B	62
11:22:33:44:55:67	C	62

FIG.4

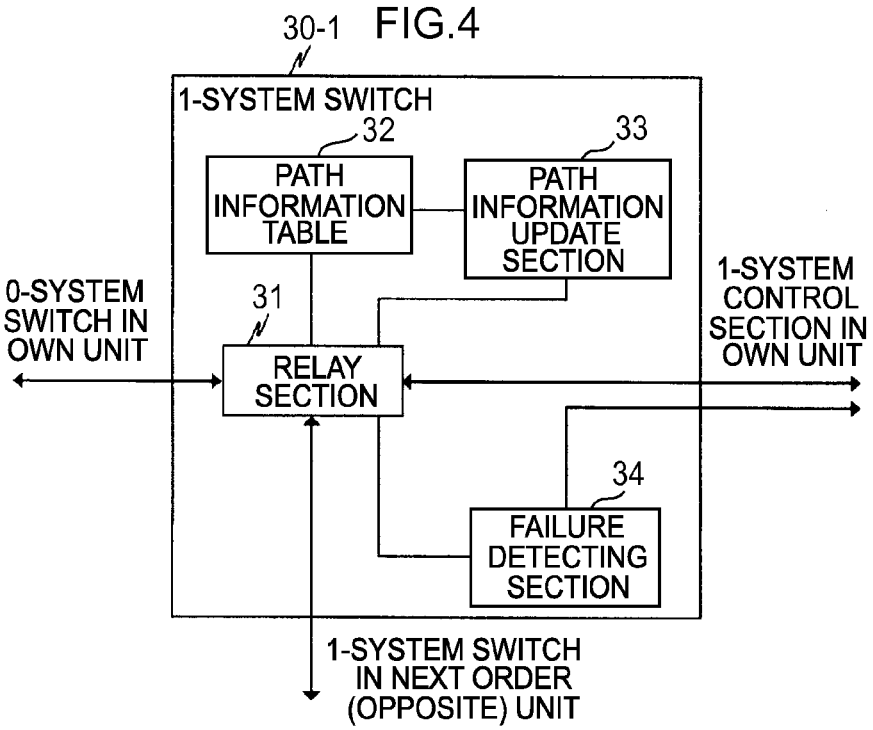

30-1
1-SYSTEM SWITCH
32
PATH INFORMATION TABLE
33
PATH INFORMATION UPDATE SECTION
0-SYSTEM SWITCH IN OWN UNIT
31
RELAY SECTION
1-SYSTEM CONTROL SECTION IN OWN UNIT
34
FAILURE DETECTING SECTION
1-SYSTEM SWITCH IN NEXT ORDER (OPPOSITE) UNIT

FIG.5

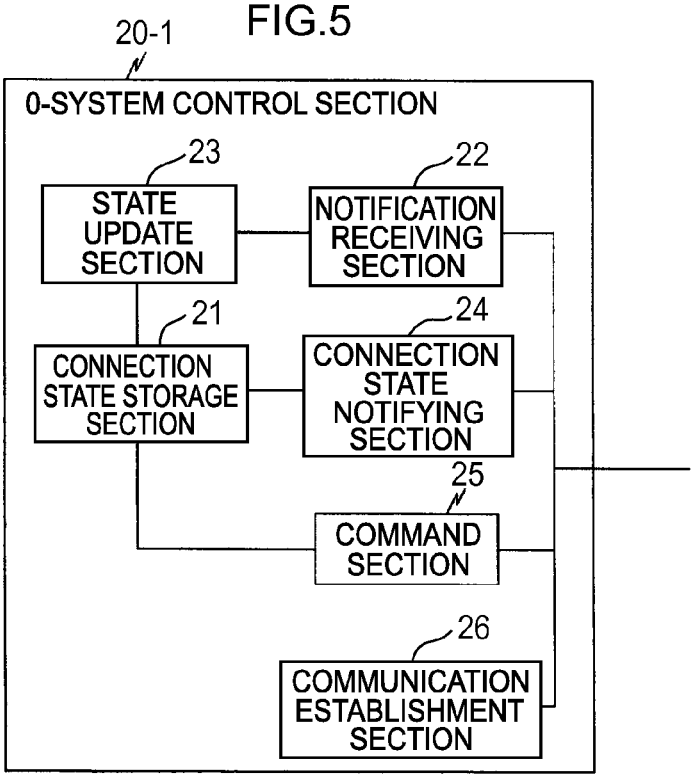

20-1
0-SYSTEM CONTROL SECTION
23
STATE UPDATE SECTION
22
NOTIFICATION RECEIVING SECTION
21
CONNECTION STATE STORAGE SECTION
24
CONNECTION STATE NOTIFYING SECTION
25
COMMAND SECTION
26
COMMUNICATION ESTABLISHMENT SECTION

FIG.6

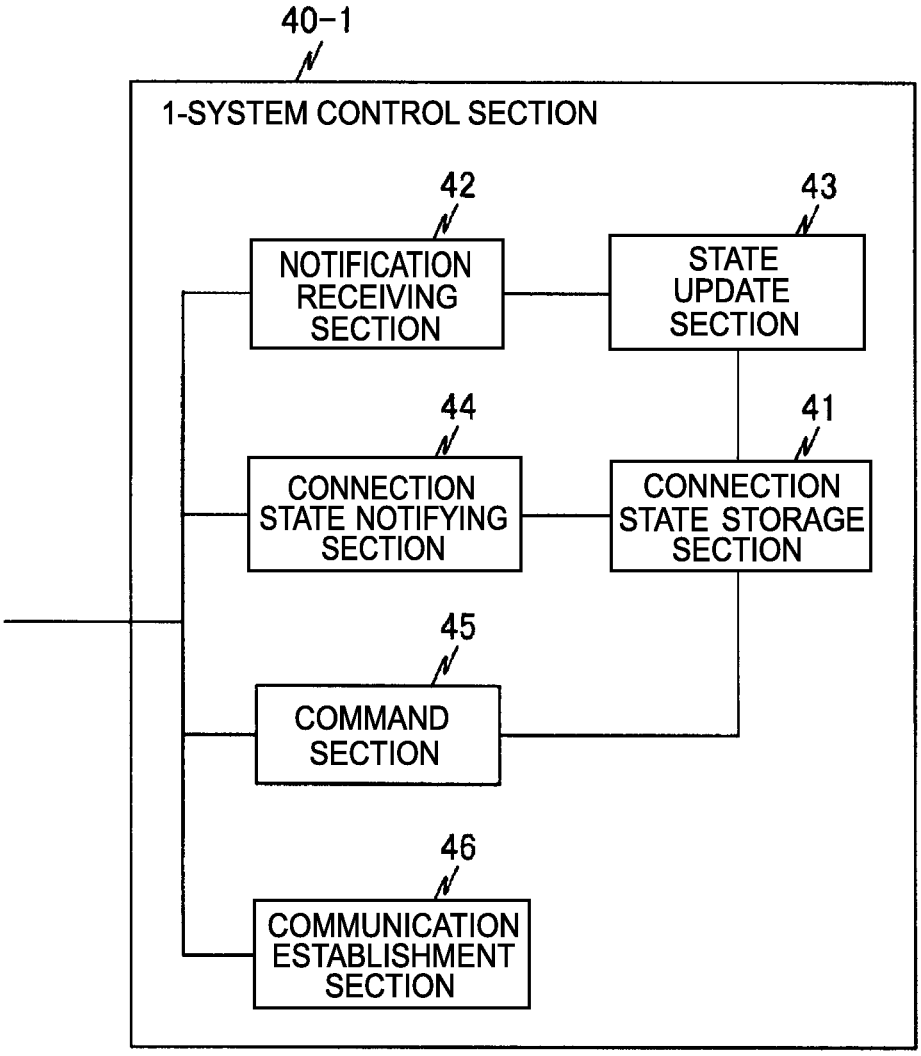

40-1
1-SYSTEM CONTROL SECTION
42
NOTIFICATION RECEIVING SECTION
43
STATE UPDATE SECTION
44
CONNECTION STATE NOTIFYING SECTION
41
CONNECTION STATE STORAGE SECTION
45
COMMAND SECTION
46
COMMUNICATION ESTABLISHMENT SECTION

FIG.7

NUMBER	CONNECTION STATE NAME	STATE
1	INDEPENDENT STATE	STATE IN WHICH COMMUNICATION BETWEEN OWN CONTROL SECTION AND OTHER SYSTEM-CONTROL SECTION IN OWN UNIT CANNOT BE ESTABLISHED AND STATE IN WHICH COMMUNICATION BETWEEN OWN CONTROL SECTION AND OPPOSITE CONTROL SECTION CANNOT BE ESTABLISHED INITIAL STATE OF CONTROL SECTION
2	PERFECT STATE	STATE IN WHICH NO FAILURE OCCURS IN OWN UNIT, IN OPPOSITE UNIT, AND BETWEEN OWN UNIT AND OPPOSITE UNIT
3	FAILURE BETWEEN UNITS IN OTHER SYSTEM	STATE IN WHICH COMMUNICATION IS ESTABLISHED BETWEEN OWN CONTROL SECTION AND OTHER SYSTEM-CONTROL SECTION IN OWN UNIT AND BETWEEN OWN CONTROL SECTION AND OPPOSITE CONTROL SECTION, BUT FAILURE OCCURS BETWEEN OTHER SYSTEM-SWITCH IN OWN UNIT AND OPPOSITE SWITCH
4	FAILURE BETWEEN UNITS IN OWN SYSTEM	STATE IN WHICH COMMUNICATION IS ESTABLISHED BETWEEN OWN CONTROL SECTION AND OTHER SYSTEM-CONTROL SECTION IN OWN UNIT AND BETWEEN OTHER SYSTEM-CONTROL SECTION IN OWN UNIT AND OPPOSITE CONTROL SECTION, BUT FAILURE OCCURS BETWEEN OWN CONTROL SECTION AND OPPOSITE CONTROL SECTION
5	FAILURE IN OPPOSITE UNIT	STATE IN WHICH COMMUNICATION IS ESTABLISHED BETWEEN OWN CONTROL SECTION AND OTHER SYSTEM-CONTROL SECTION IN OWN UNIT, BETWEEN OWN CONTROL SECTION AND OPPOSITE CONTROL SECTION, AND BETWEEN OTHER SYSTEM-CONTROL SECTION IN OWN UNIT AND OPPOSITE CONTROL SECTION, BUT COMMUNICATION BETWEEN TWO CONTROL SECTIONS IN OPPOSITE UNIT CANNOT BE ESTABLISHED
6	FAILURE IN OWN UNIT	STATE IN WHICH COMMUNICATION BETWEEN OWN CONTROL SECTION AND OTHER SYSTEM-CONTROL SECTION IN OWN UNIT CANNOT BE ESTABLISHED, ALTHOUGH COMMUNICATION IS ESTABLISHED BETWEEN TWO CONTROL SECTIONS IN OWN UNIT AND TWO CONTROL SECTIONS IN OPPOSITE UNIT
7	DOUBLE FAILURE BETWEEN UNITS	STATE IN WHICH COMMUNICATION BETWEEN OWN CONTROL SECTION AND OTHER SYSTEM-CONTROL SECTION IN OWN UNIT IS ESTABLISHED, BUT FAILURE OCCURS BETWEEN OWN SWITCH AND OPPOSITE SWITCH AND BETWEEN OTHER SYSTEM-SWITCH IN OWN UNIT AND OPPOSITE SWITCH
8	SIMPLEX STATE	STATE IN WHICH COMMUNICATION IS ESTABLISHED BETWEEN OWN CONTROL SECTION AND OPPOSITE CONTROL SECTION, BUT COMMUNICATION CANNOT BE ESTABLISHED BETWEEN OWN CONTROL SECTION AND OTHER SYSTEM-CONTROL SECTION IN OWN UNIT AND BETWEEN TWO CONTROL SECTIONS IN OPPOSITE UNIT
9	FAILURE IN OPPOSITE UNIT AND FAILURE BETWEEN UNITS IN OTHER SYSTEM	STATE IN WHICH COMMUNICATION IS ESTABLISHED BETWEEN OWN CONTROL SECTION AND OTHER SYSTEM-CONTROL SECTION IN OWN UNIT AND BETWEEN OWN CONTROL SECTION AND OPPOSITE CONTROL SECTION, BUT COMMUNICATION CANNOT BE ESTABLISHED BETWEEN TWO CONTROL SECTIONS IN OPPOSITE UNIT AND BETWEEN OTHER SYSTEM-CONTROL SECTION AND OPPOSITE CONTROL SECTION

FIG.8

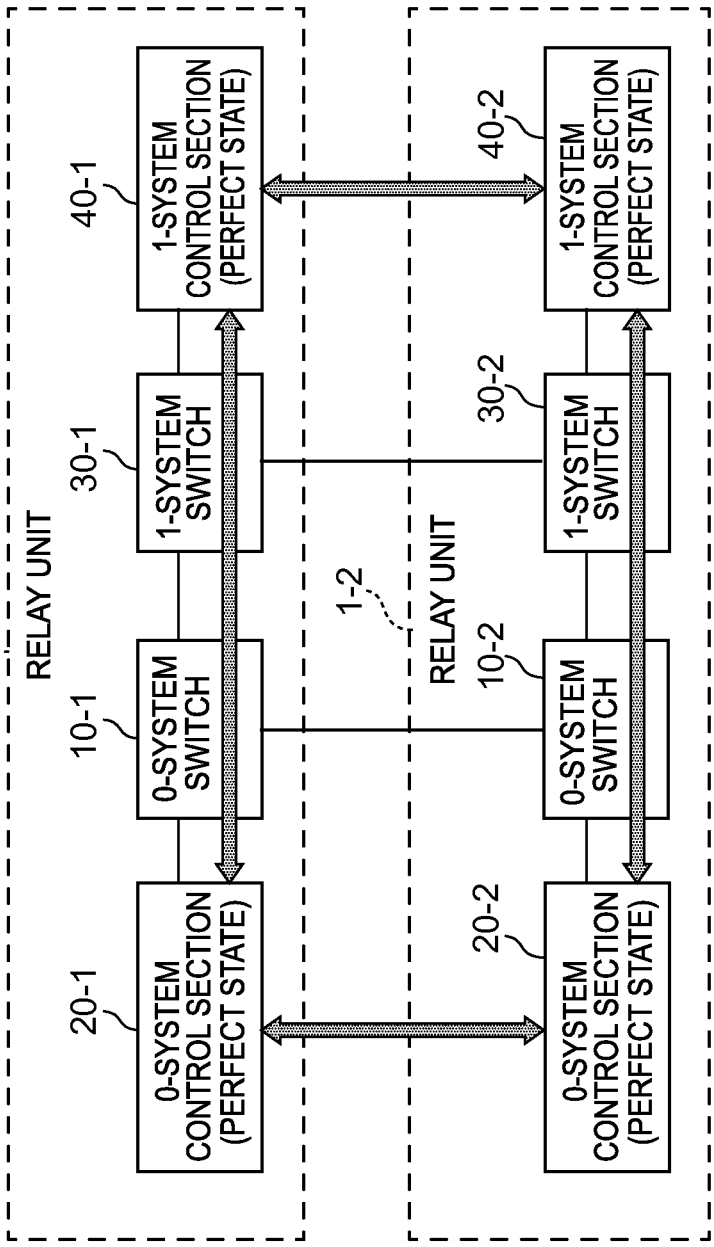

1-1
RELAY UNIT
1-2
RELAY UNIT
40-1
1-SYSTEM CONTROL SECTION (PERFECT STATE)
40-2
1-SYSTEM CONTROL SECTION (PERFECT STATE)
30-1
1-SYSTEM SWITCH
30-2
1-SYSTEM SWITCH
10-1
0-SYSTEM SWITCH
10-2
0-SYSTEM SWITCH
20-1
0-SYSTEM CONTROL SECTION (PERFECT STATE)
20-2
0-SYSTEM CONTROL SECTION (PERFECT STATE)

FIG.9

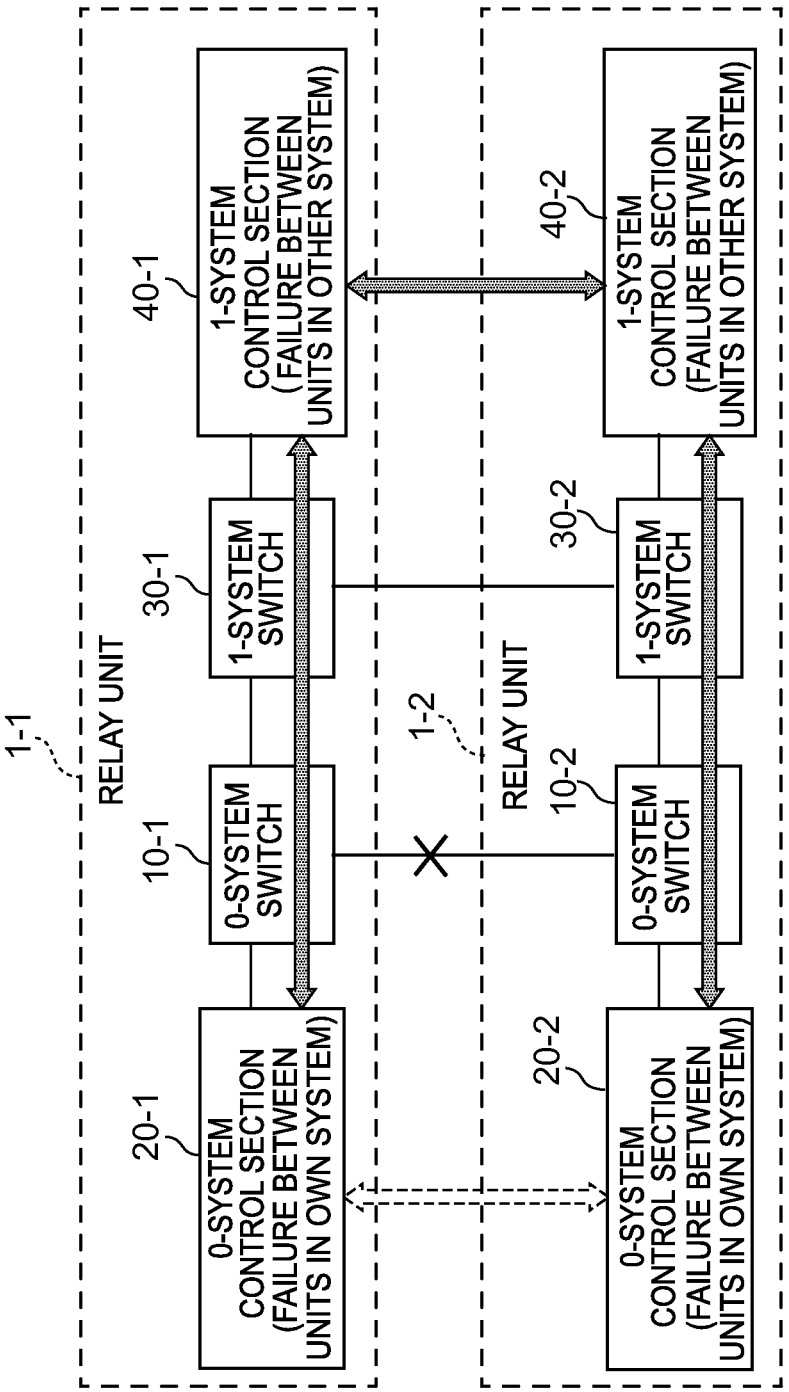

1-1
RELAY UNIT
1-2
RELAY UNIT
40-1
1-SYSTEM CONTROL SECTION (FAILURE BETWEEN UNITS IN OTHER SYSTEM)
40-2
1-SYSTEM CONTROL SECTION (FAILURE BETWEEN UNITS IN OTHER SYSTEM)
30-1
1-SYSTEM SWITCH
30-2
1-SYSTEM SWITCH
10-1
0-SYSTEM SWITCH
10-2
0-SYSTEM SWITCH
20-1
0-SYSTEM CONTROL SECTION (FAILURE BETWEEN UNITS IN OWN SYSTEM)
20-2
0-SYSTEM CONTROL SECTION (FAILURE BETWEEN UNITS IN OWN SYSTEM)

FIG.10

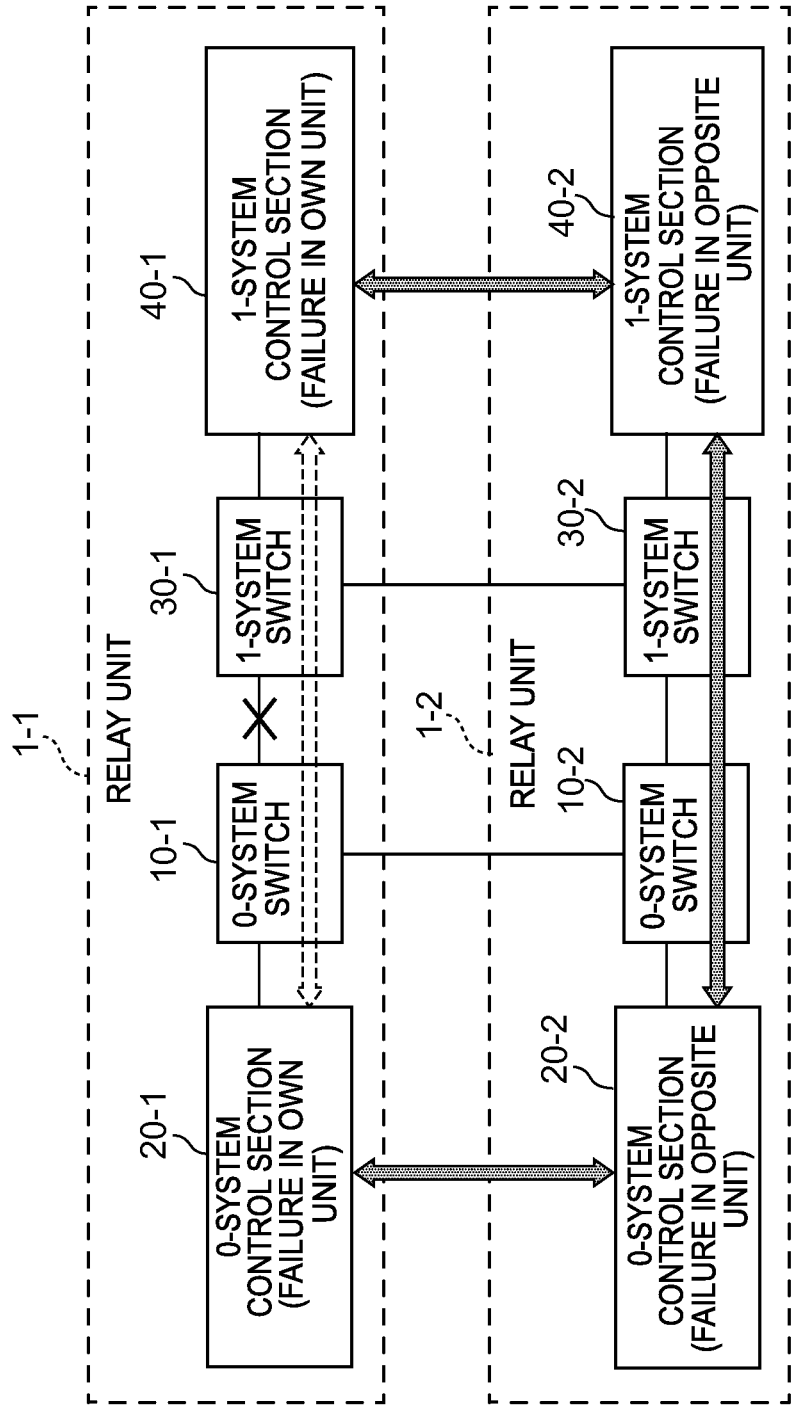

1-1
RELAY UNIT
1-2
RELAY UNIT
40-1
1-SYSTEM CONTROL SECTION (FAILURE IN OWN UNIT)
40-2
1-SYSTEM CONTROL SECTION (FAILURE IN OPPOSITE UNIT)
30-1
1-SYSTEM SWITCH
30-2
1-SYSTEM SWITCH
10-1
0-SYSTEM SWITCH
10-2
0-SYSTEM SWITCH
20-1
0-SYSTEM CONTROL SECTION (FAILURE IN OWN UNIT)
20-2
0-SYSTEM CONTROL SECTION (FAILURE IN OPPOSITE UNIT)

FIG.11

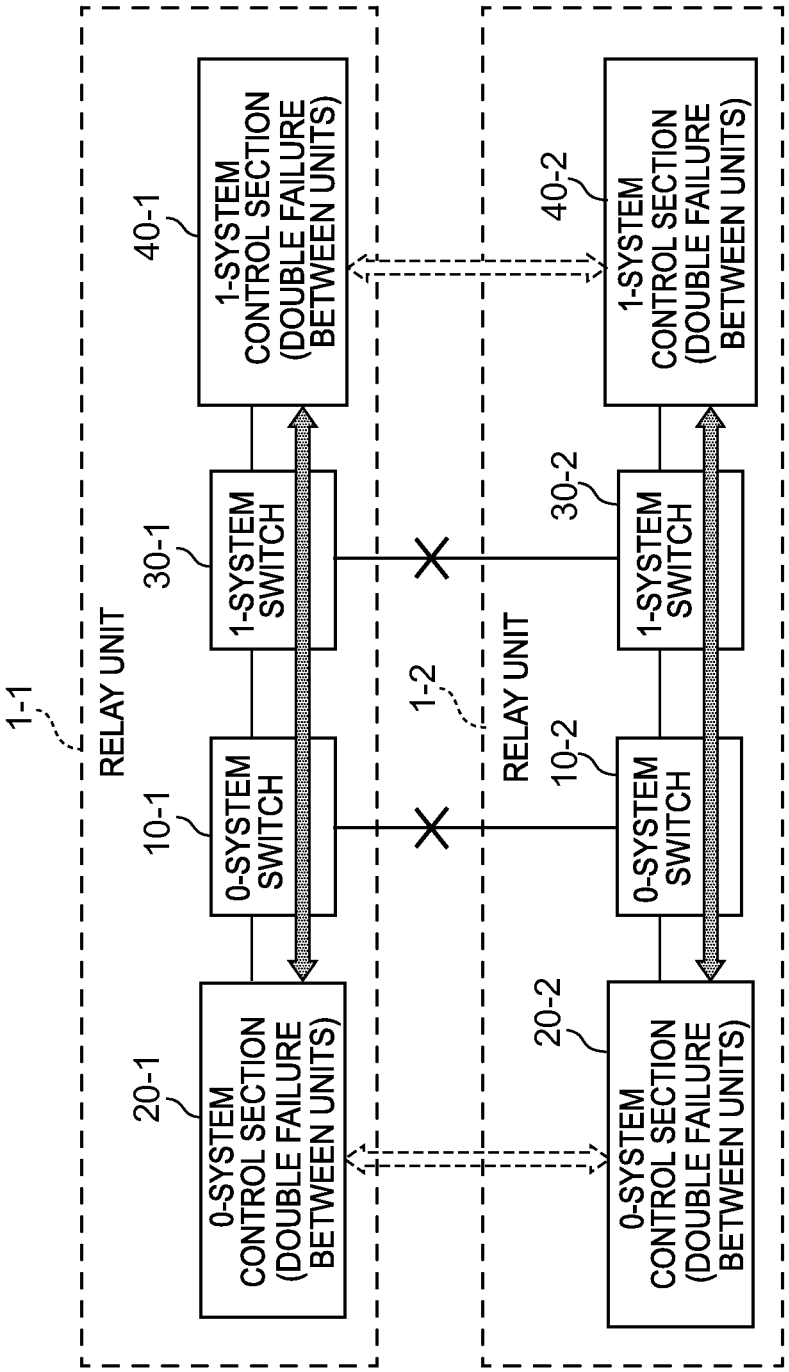

1-1
RELAY UNIT
1-2
RELAY UNIT
40-1
1-SYSTEM CONTROL SECTION (DOUBLE FAILURE BETWEEN UNITS)
40-2
1-SYSTEM CONTROL SECTION (DOUBLE FAILURE BETWEEN UNITS)
30-1
1-SYSTEM SWITCH
30-2
1-SYSTEM SWITCH
10-1
0-SYSTEM SWITCH
10-2
0-SYSTEM SWITCH
20-1
0-SYSTEM CONTROL SECTION (DOUBLE FAILURE BETWEEN UNITS)
20-2
0-SYSTEM CONTROL SECTION (DOUBLE FAILURE BETWEEN UNITS)

FIG.12

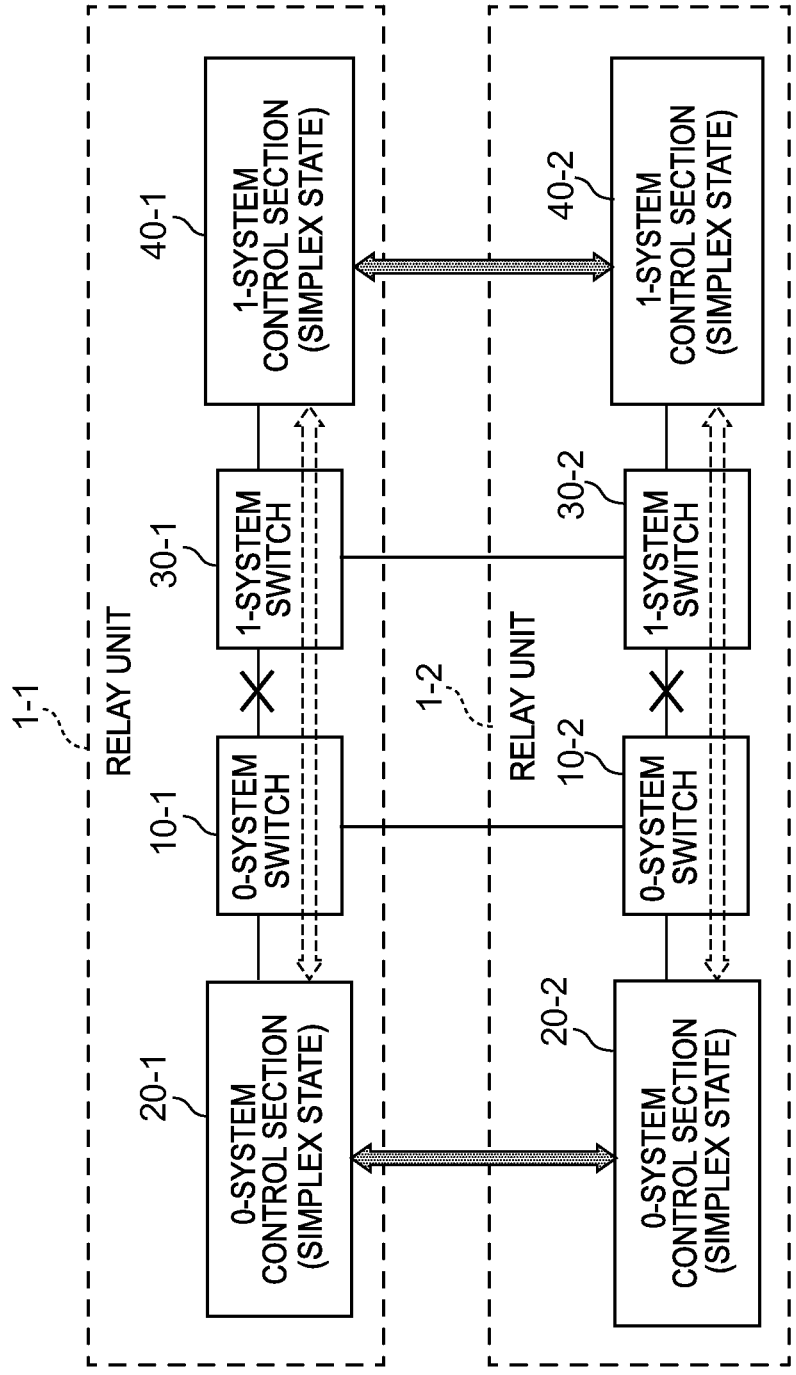

1-1
RELAY UNIT
1-2
RELAY UNIT
40-1
1-SYSTEM CONTROL SECTION (SIMPLEX STATE)
40-2
1-SYSTEM CONTROL SECTION (SIMPLEX STATE)
30-1
1-SYSTEM SWITCH
30-2
1-SYSTEM SWITCH
10-1
0-SYSTEM SWITCH
10-2
0-SYSTEM SWITCH
20-1
0-SYSTEM CONTROL SECTION (SIMPLEX STATE)
20-2
0-SYSTEM CONTROL SECTION (SIMPLEX STATE)

FIG.13

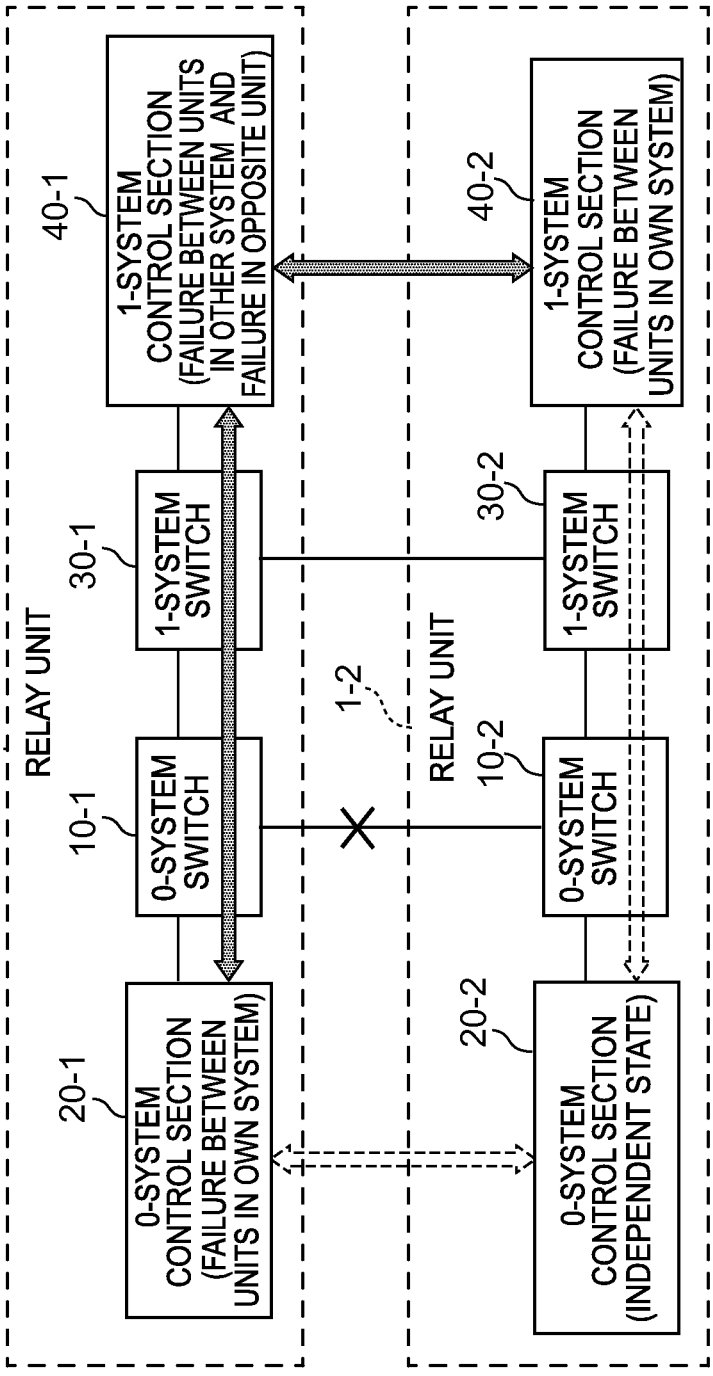

1-1
RELAY UNIT
40-1
1-SYSTEM CONTROL SECTION (FAILURE BETWEEN UNITS IN OTHER SYSTEM AND FAILURE IN OPPOSITE UNIT)
30-1
1-SYSTEM SWITCH
10-1
0-SYSTEM SWITCH
20-1
0-SYSTEM CONTROL SECTION (FAILURE BETWEEN UNITS IN OWN SYSTEM)
1-2
RELAY UNIT
40-2
1-SYSTEM CONTROL SECTION (FAILURE BETWEEN UNITS IN OWN SYSTEM)
30-2
1-SYSTEM SWITCH
10-2
0-SYSTEM SWITCH
20-2
0-SYSTEM CONTROL SECTION (INDEPENDENT STATE)

FIG.14

NOTIFICATION INFORMATION NAME	CONTENT OF NOTIFICATION	NOTIFICATION DESTINATION
CONNECTION STATE	CONNECTION INFORMATION STORED IN CONTROL SECTION	OTHER SYSTEM-CONTROL SECTION IN OWN UNIT AND OPPOSITE CONTROL SECTION
OCCURRENCE OF FAILURE BETWEEN UNITS	NOTIFY DETECTION OF COMMUNICATION FAILURE WITH OPPOSITE SWITCH BY OWN SWITCH OR NOTIFY DETECTION OF COMMUNICATION FAILURE WITH OPPOSITE CONTROL SECTION	OTHER SYSTEM-CONTROL SECTION IN OWN UNIT
ESTABLISHMENT OF COMMUNICATION BETWEEN UNITS	NOTIFY ESTABLISHMENT OF COMMUNICATION WITH OPPOSITE CONTROL SECTION	OTHER SYSTEM-CONTROL SECTION IN OWN UNIT
OCCURRENCE OF FAILURE IN UNIT	NOTIFY DETECTION OF COMMUNICATION FAILURE WITH OTHER SYSTEM-SWITCH BY OWN SWITCH OR NOTIFY DETECTION OF COMMUNICATION FAILURE WITH OTHER SYSTEM CONTROL SECTION IN OWN UNIT	OPPOSITE CONTROL SECTION
ESTABLISHMENT OF COMMUNICATION IN UNIT	NOTIFY ESTABLISHMENT OF COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION IN OWN UNIT	OPPOSITE CONTROL SECTION

FIG.15

NUMBER	COMMAND NAME	CONTENT OF COMMAND
COMMAND 1	COMMAND TO PERMIT RELAY TO OTHER SYSTEM-SWITCH	PERMIT RELAY OF USER TRAFFIC TO OTHER SYSTEM-SWITCH
COMMAND 2	COMMAND TO PERMIT RELAY TO OPPOSITE SWITCH	PERMIT RELAY OF USER TRAFFIC TO OPPOSITE SWITCH
COMMAND 3	COMMAND TO PROHIBIT RELAY TO OTHER SYSTEM-SWITCH	COMMAND WHICH IS NOTIFIED AFTER COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION IS DISCONNECTED AND WHICH PROHIBITS RELAY OF USER TRAFFIC TO OTHER SYSTEM-SWITCH
COMMAND 4	COMMAND TO PROHIBIT RELAY TO OPPOSITE SWITCH	COMMAND WHICH IS NOTIFIED AFTER COMMUNICATION WITH OPPOSITE CONTROL SECTION IS DISCONNECTED AND WHICH PROHIBITS RELAY OF USER TRAFFIC TO OPPOSITE SWITCH
COMMAND 5	RELAY SUPPRESSION VALIDATION COMMAND	SUPPRESS PROCESSING FOR RELAYING USER TRAFFIC RECEIVED FROM OTHER SYSTEM-SWITCH TO OPPOSITE SWITCH
COMMAND 6	RELAY SUPPRESSION INVALIDATION COMMAND	RELEASE SUPPRESSION OF PROCESSING FOR RELAYING USER TRAFFIC RECEIVED FROM OTHER SYSTEM-SWITCH TO OPPOSITE SWITCH
COMMAND 7	COMMAND TO DELETE PATH TO OPPOSITE SWITCH	DELETE MAC ADDRESS WHOSE TRANSMISSION PATH IS SET TO OPPOSITE SWITCH FROM PATH CONTROL TABLE
COMMAND 8	COMMAND TO DELETE PATH TO OTHER SYSTEM-SWITCH	DELETE MAC ADDRESS WHOSE TRANSMISSION PATH IS SET TO OTHER SYSTEM-SWITCH FROM PATH CONTROL TABLE

FIG.16

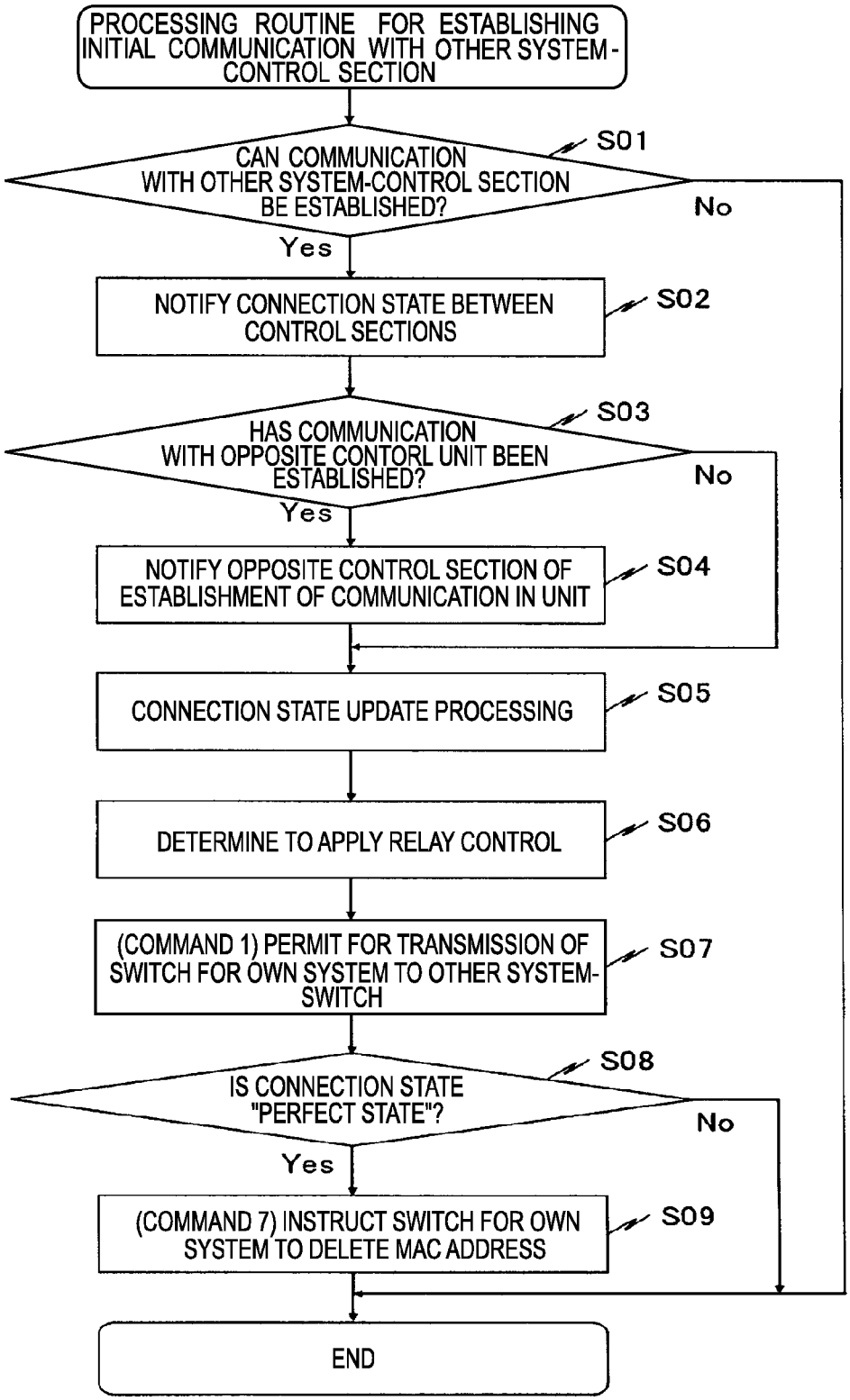

PROCESSING ROUTINE FOR ESTABLISHING INITIAL COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION
S01
CAN COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION BE ESTABLISHED?
No
Yes
NOTIFY CONNECTION STATE BETWEEN CONTROL SECTIONS
S02
S03
HAS COMMUNICATION WITH OPPOSITE CONTORL UNIT BEEN ESTABLISHED?
No
Yes
NOTIFY OPPOSITE CONTROL SECTION OF ESTABLISHMENT OF COMMUNICATION IN UNIT
S04
CONNECTION STATE UPDATE PROCESSING
S05
DETERMINE TO APPLY RELAY CONTROL
S06
(COMMAND 1) PERMIT FOR TRANSMISSION OF SWITCH FOR OWN SYSTEM TO OTHER SYSTEM-SWITCH
S07
S08
IS CONNECTION STATE "PERFECT STATE"?
No
Yes
(COMMAND 7) INSTRUCT SWITCH FOR OWN SYSTEM TO DELETE MAC ADDRESS
S09
END

FIG. 17

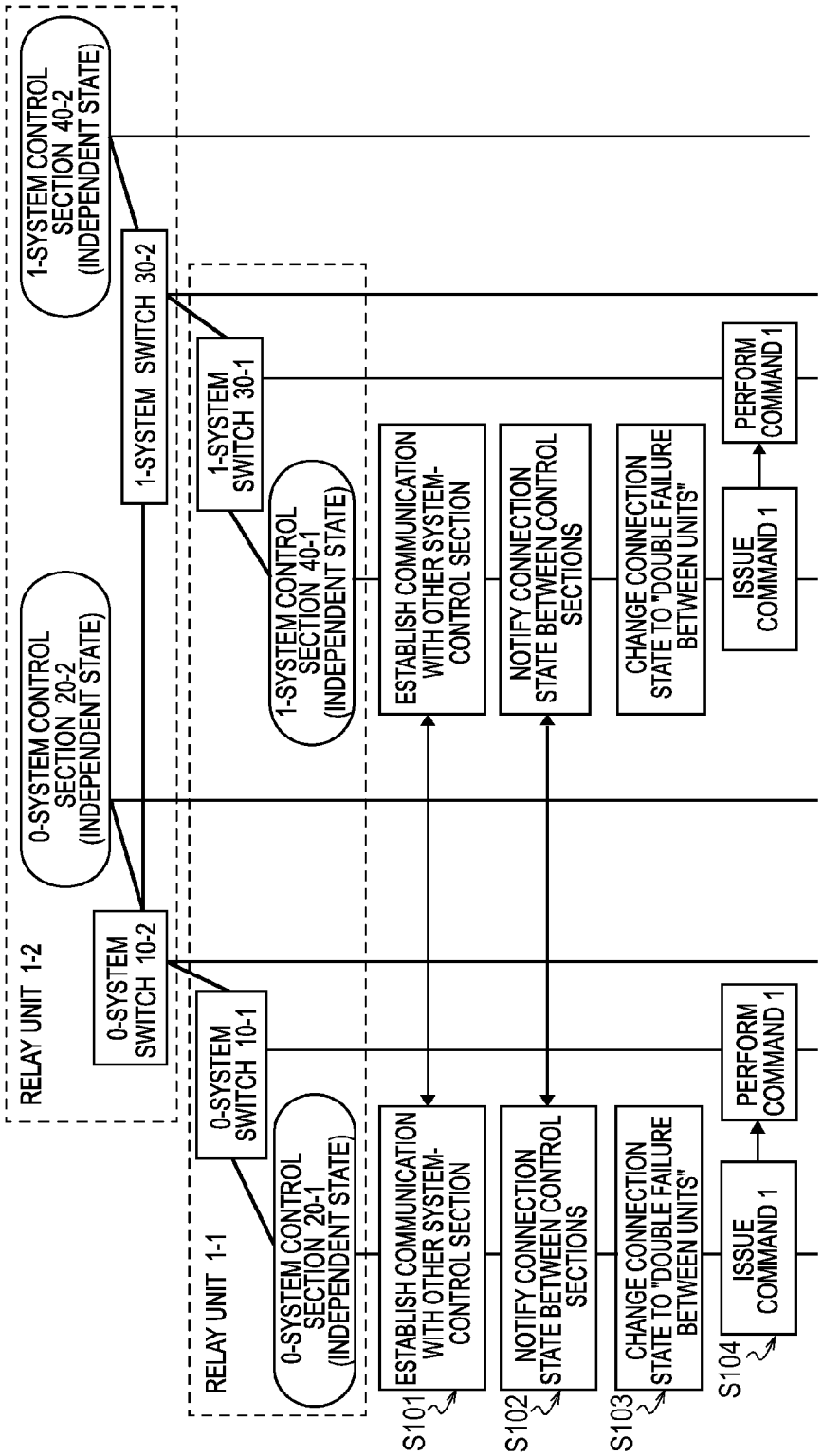

RELAY UNIT 1-2
0-SYSTEM CONTROL SECTION 20-2 (INDEPENDENT STATE)
1-SYSTEM CONTROL SECTION 40-2 (INDEPENDENT STATE)
0-SYSTEM SWITCH 10-2
1-SYSTEM SWITCH 30-2
RELAY UNIT 1-1
0-SYSTEM CONTROL SECTION 20-1 (INDEPENDENT STATE)
1-SYSTEM CONTROL SECTION 40-1 (INDEPENDENT STATE)
0-SYSTEM SWITCH 10-1
1-SYSTEM SWITCH 30-1
ESTABLISH COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION
NOTIFY CONNECTION STATE BETWEEN CONTROL SECTIONS
CHANGE CONNECTION STATE TO "DOUBLE FAILURE BETWEEN UNITS"
ISSUE COMMAND 1
PERFORM COMMAND 1
S101
S102
S103
S104

FIG.18

CONNECTION STATE OF OTHER SYSTEM-CONTROL SECTION / CONNECTION STATE OF OWN CONTROL SECTION	INDEPENDENT STATE	SIMPLEX STATE	FAILURE IN OWN UNIT
INDEPENDENT STATE	DOUBLE FAILURE BETWEEN UNITS	FAILURE BETWEEN UNITS IN OWN SYSTEM	FAILURE BETWEEN UNITS IN OWN SYSTEM
SIMPLEX STATE	FAILURE BETWEEN UNITS IN OTHER SYSTEM AND FAILURE IN OPPOSITE UNIT	FAILURE IN OPPOSITE UNIT	NO CASE
FAILURE IN OWN UNIT	FAILURE BETWEEN UNITS IN OTHER SYSTEM	NO CASE	PERFECT STATE

FIG.19

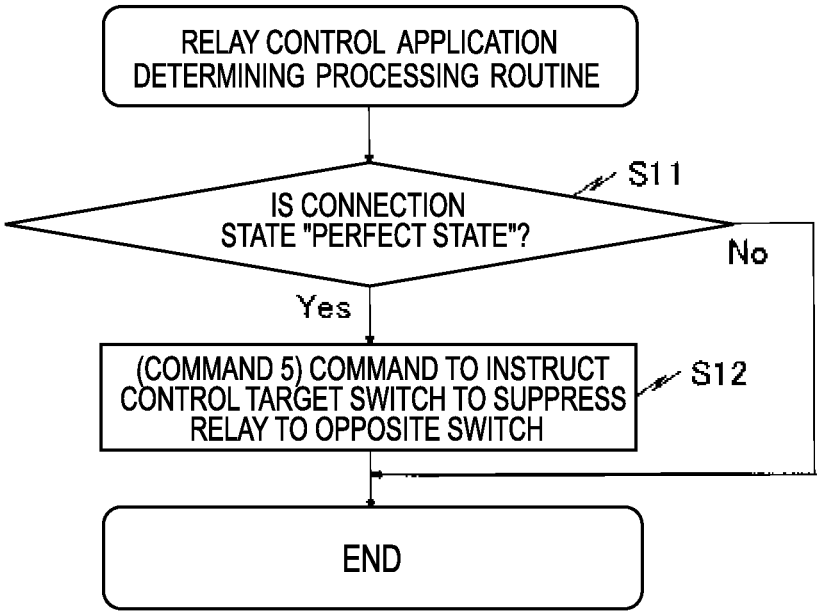

RELAY CONTROL APPLICATION DETERMINING PROCESSING ROUTINE
S11
IS CONNECTION STATE "PERFECT STATE"?
No
Yes
(COMMAND 5) COMMAND TO INSTRUCT CONTROL TARGET SWITCH TO SUPPRESS RELAY TO OPPOSITE SWITCH
S12
END

FIG.20

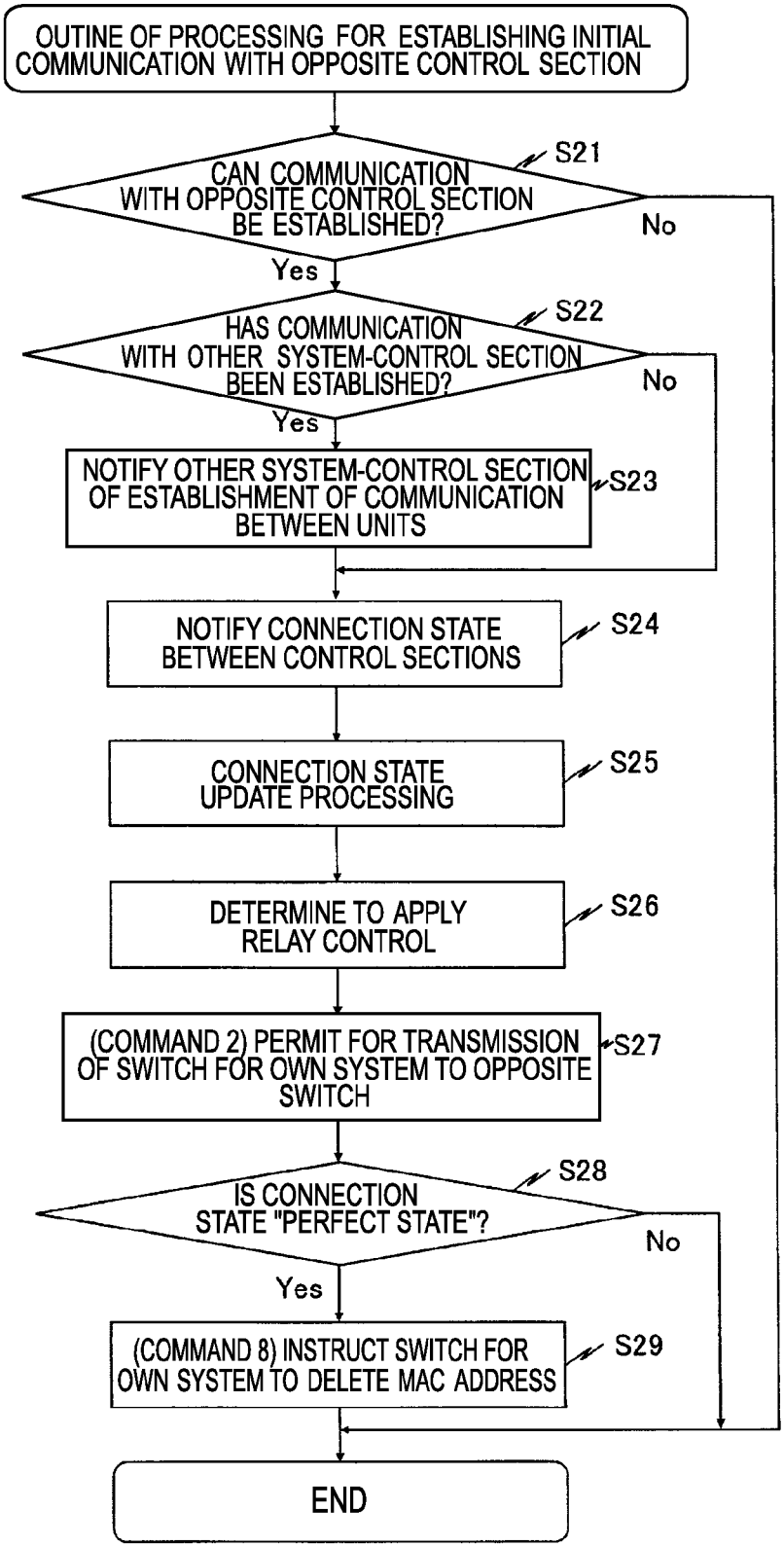

OUTINE OF PROCESSING FOR ESTABLISHING INITIAL COMMUNICATION WITH OPPOSITE CONTROL SECTION
S21
CAN COMMUNICATION WITH OPPOSITE CONTROL SECTION BE ESTABLISHED?
No
Yes
S22
HAS COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION BEEN ESTABLISHED?
No
Yes
NOTIFY OTHER SYSTEM-CONTROL SECTION OF ESTABLISHMENT OF COMMUNICATION BETWEEN UNITS
S23
NOTIFY CONNECTION STATE BETWEEN CONTROL SECTIONS
S24
CONNECTION STATE UPDATE PROCESSING
S25
DETERMINE TO APPLY RELAY CONTROL
S26
(COMMAND 2) PERMIT FOR TRANSMISSION OF SWITCH FOR OWN SYSTEM TO OPPOSITE SWITCH
S27
S28
IS CONNECTION STATE "PERFECT STATE"?
No
Yes
(COMMAND 8) INSTRUCT SWITCH FOR OWN SYSTEM TO DELETE MAC ADDRESS
S29
END

FIG.21

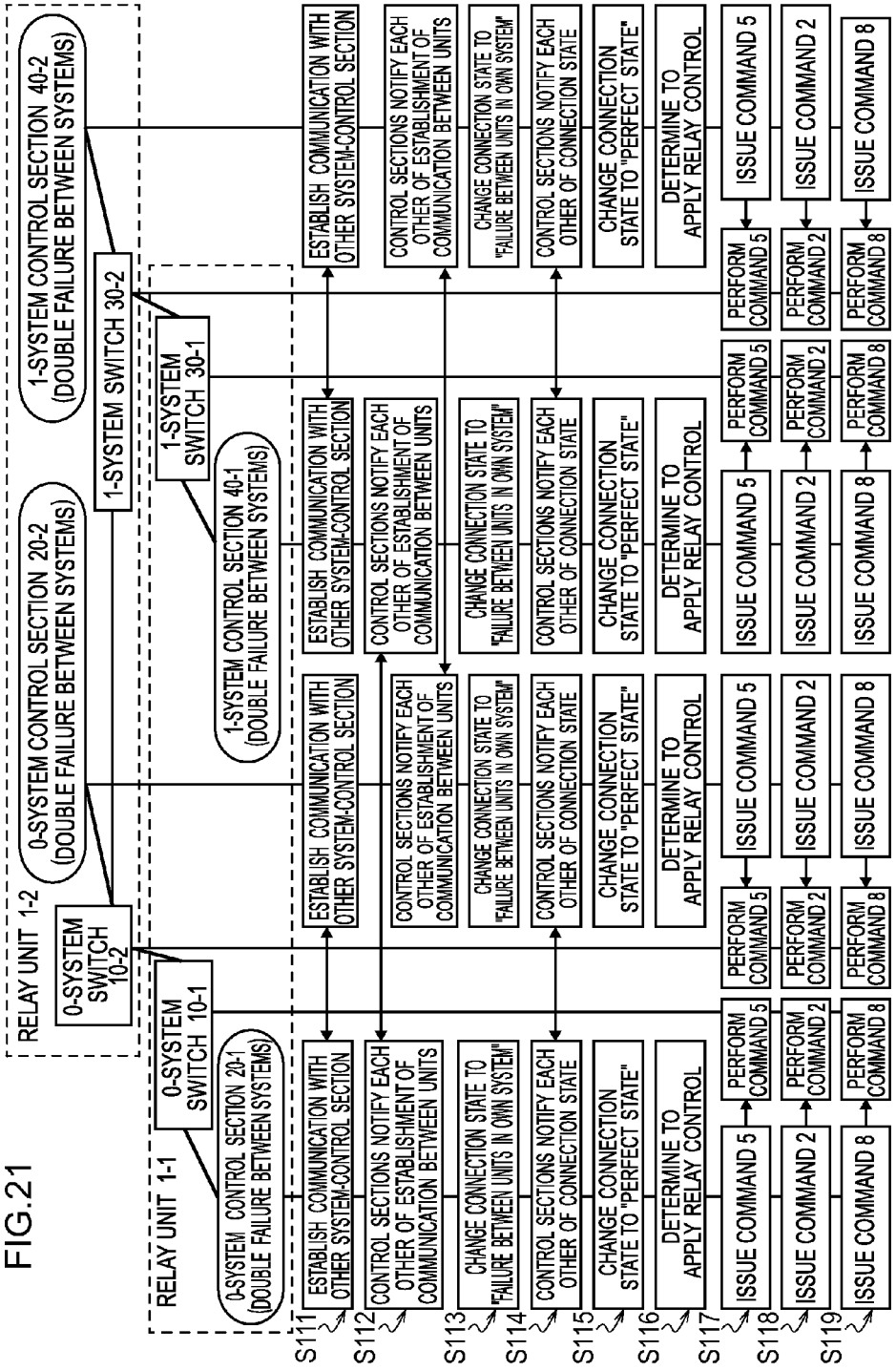

RELAY UNIT 1-2
0-SYSTEM SWITCH 10-2
0-SYSTEM CONTROL SECTION 20-2 (DOUBLE FAILURE BETWEEN SYSTEMS)
1-SYSTEM SWITCH 30-2
1-SYSTEM CONTROL SECTION 40-2 (DOUBLE FAILURE BETWEEN SYSTEMS)
RELAY UNIT 1-1
0-SYSTEM SWITCH 10-1
0-SYSTEM CONTROL SECTION 20-1 (DOUBLE FAILURE BETWEEN SYSTEMS)
1-SYSTEM SWITCH 30-1
1-SYSTEM CONTROL SECTION 40-1 (DOUBLE FAILURE BETWEEN SYSTEMS)
ESTABLISH COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION
CONTROL SECTIONS NOTIFY EACH OTHER OF ESTABLISHMENT OF COMMUNICATION BETWEEN UNITS
CHANGE CONNECTION STATE TO "FAILURE BETWEEN UNITS IN OWN SYSTEM"
CONTROL SECTIONS NOTIFY EACH OTHER OF CONNECTION STATE
CHANGE CONNECTION STATE TO "PERFECT STATE"
DETERMINE TO APPLY RELAY CONTROL
ISSUE COMMAND 5
ISSUE COMMAND 2
ISSUE COMMAND 8
PERFORM COMMAND 5
PERFORM COMMAND 2
PERFORM COMMAND 8
S111
S112
S113
S114
S115
S116
S117
S118
S119

FIG.22

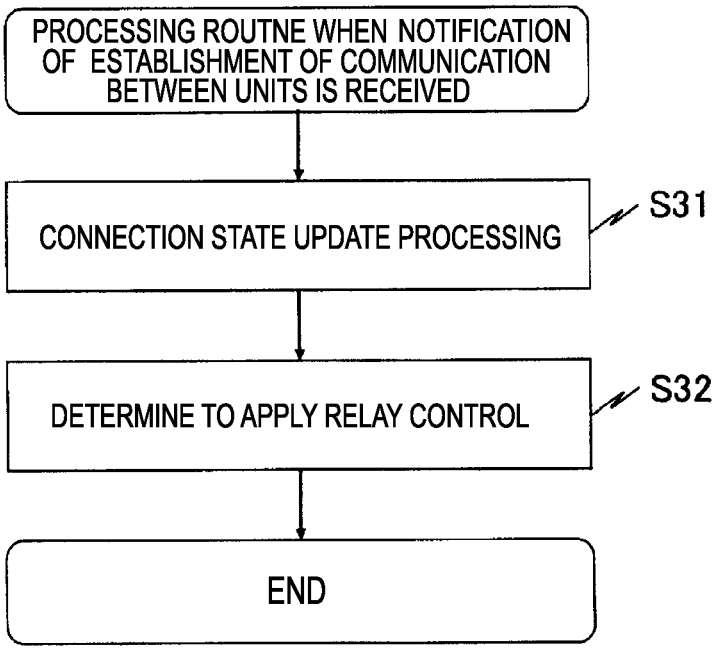

PROCESSING ROUTNE WHEN NOTIFICATION OF ESTABLISHMENT OF COMMUNICATION BETWEEN UNITS IS RECEIVED
CONNECTION STATE UPDATE PROCESSING
S31
DETERMINE TO APPLY RELAY CONTROL
S32
END

FIG.23

CONNECTION STATE BEFORE NOTIFICATION IS RECEIVED	CONNECTION STATE AFTER NOTIFICATION IS RECEIVED
DOUBLE FAILURE BETWEEN UNITS	FAILURE BETWEEN UNITS IN OWN SYSTEM
FAILURE BETWEEN UNITS IN OTHER SYSTEM AND FAILURE IN OPPOSITE UNIT	FAILURE IN OPPOSITE UNIT
FAILURE BETWEEN UNITS IN OTHER SYSTEM	PERFECT STATE

FIG.24

CONNECTION STATE OF OWN CONTROL SECTION \ CONNECTION STATE OF OTHER SYSTEM-CONTROL SECTION	INDEPENDENT STATE	DOUBLE FAILURE BETWEEN UNITS	FAILURE BETWEEN UNITS IN OWN SYSTEM
INDEPENDENT STATE	SIMPLEX STATE	FAILURE IN OWN UNIT	FAILURE IN OWN UNIT
DOUBLE FAILURE BETWEEN UNITS	FAILURE BETWEEN UNITS IN OTHER SYSTEM FAILURE AND IN OPPOSITE UNIT	FAILURE BETWEEN UNITS IN OTHER SYSTEM	NO CASE
FAILURE BETWEEN UNITS IN OWN SYSTEM	FAILURE IN OPPOSITE UNIT	NO CASE	PERFECT STATE

FIG.25

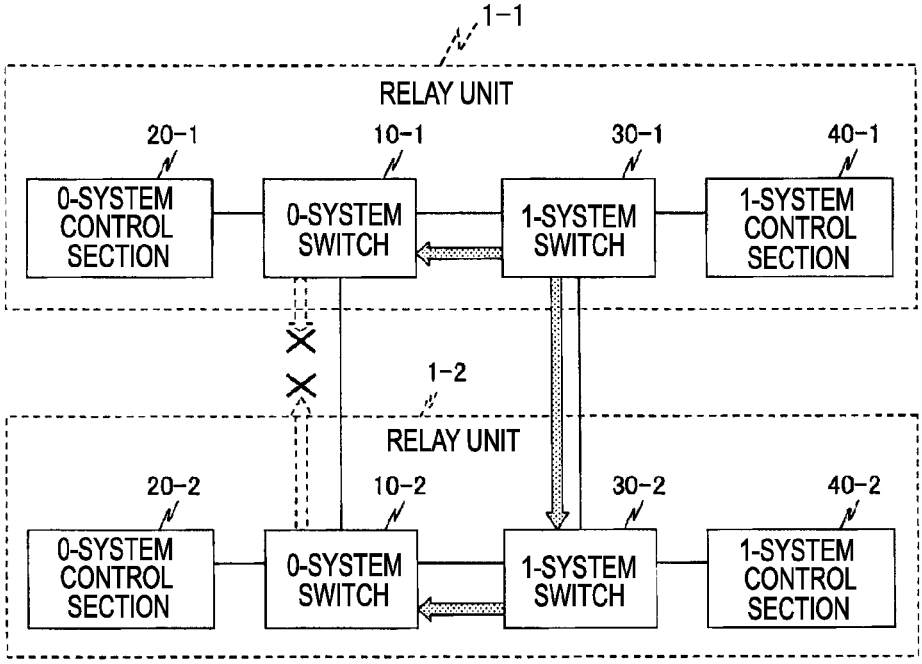

1-1
RELAY UNIT
20-1
10-1
30-1
40-1
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
1-2
RELAY UNIT
20-2
10-2
30-2
40-2
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION

FIG.26

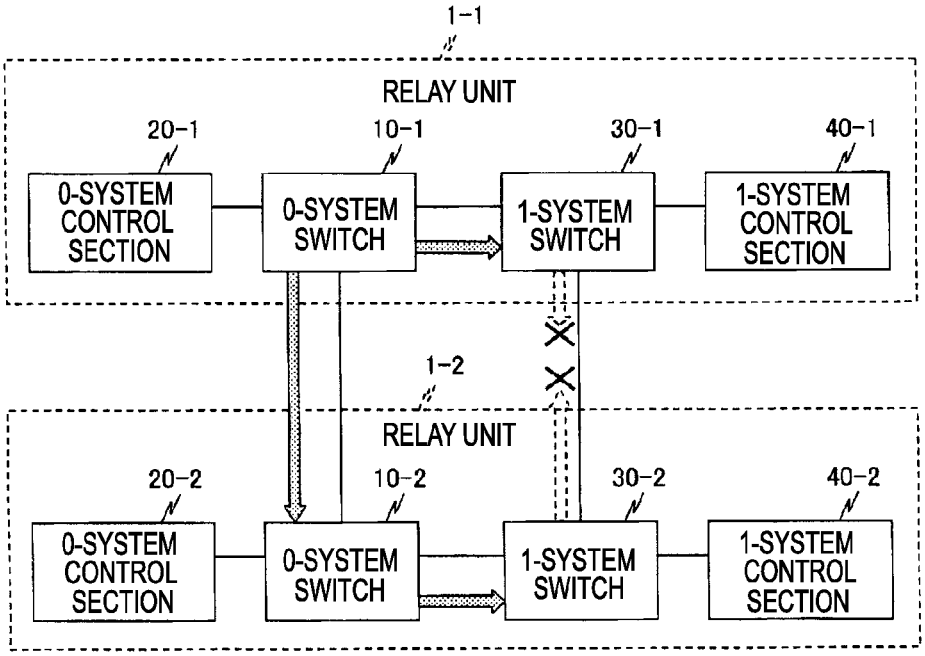

1-1
RELAY UNIT
20-1
10-1
30-1
40-1
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
1-2
RELAY UNIT
20-2
10-2
30-2
40-2
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION

FIG.27

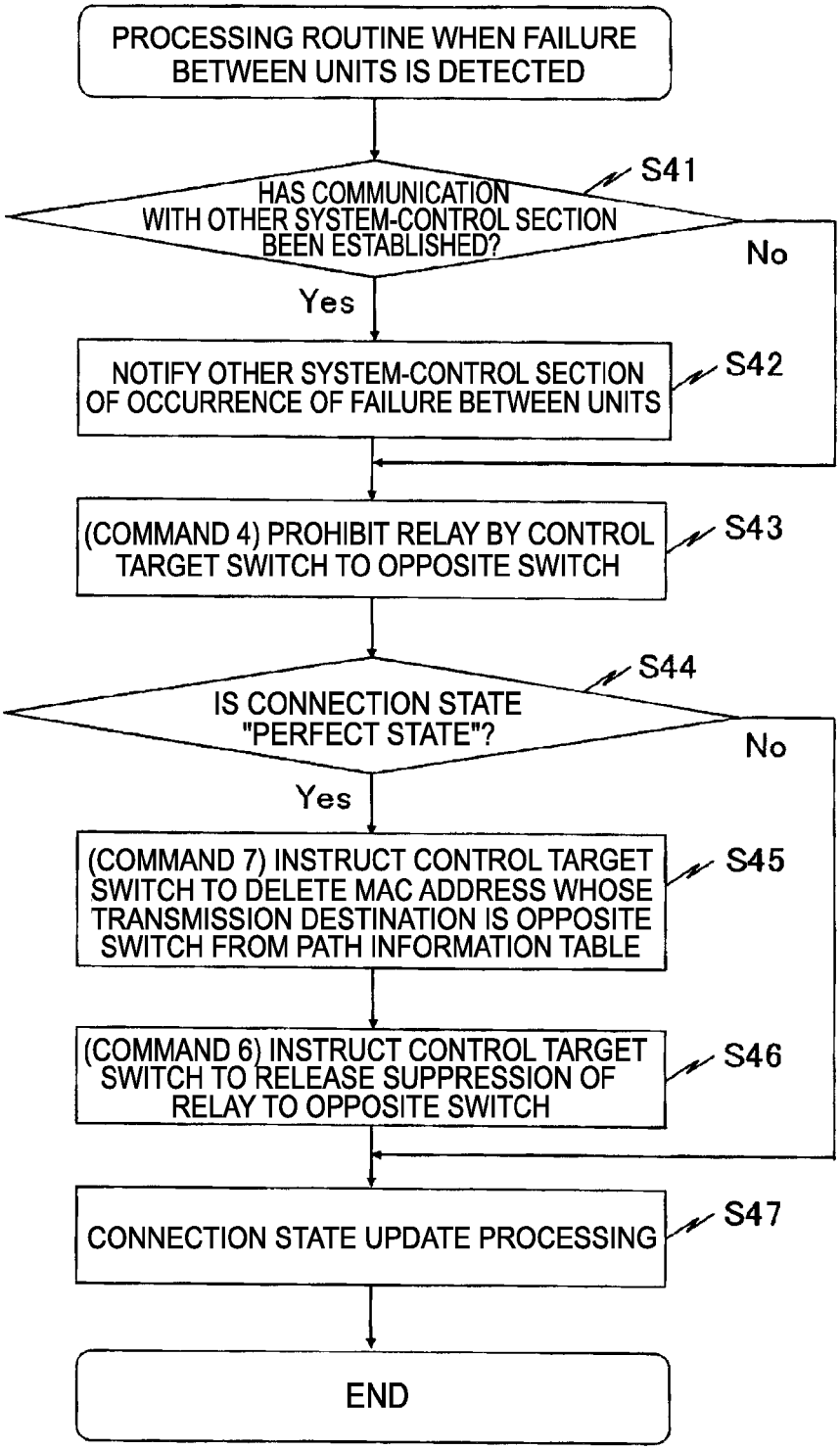

PROCESSING ROUTINE WHEN FAILURE BETWEEN UNITS IS DETECTED
S41
HAS COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION BEEN ESTABLISHED?
No
Yes
NOTIFY OTHER SYSTEM-CONTROL SECTION OF OCCURRENCE OF FAILURE BETWEEN UNITS
S42
(COMMAND 4) PROHIBIT RELAY BY CONTROL TARGET SWITCH TO OPPOSITE SWITCH
S43
S44
IS CONNECTION STATE "PERFECT STATE"?
No
Yes
(COMMAND 7) INSTRUCT CONTROL TARGET SWITCH TO DELETE MAC ADDRESS WHOSE TRANSMISSION DESTINATION IS OPPOSITE SWITCH FROM PATH INFORMATION TABLE
S45
(COMMAND 6) INSTRUCT CONTROL TARGET SWITCH TO RELEASE SUPPRESSION OF RELAY TO OPPOSITE SWITCH
S46
CONNECTION STATE UPDATE PROCESSING
S47
END

FIG.28

CONNECTION STATE BEFORE COMMUNICATION IS UNAVAILABLE	CONNECTION STATE AFTER COMMUNICATION IS UNAVAILABLE
SIMPLEX STATE	INDEPENDENT STATE
FAILURE IN OWN UNIT	INDEPENDENT STATE
FAILURE BETWEEN UNITS IN OTHER SYSTEM AND FAILURE IN OPPOSITE UNIT	DOUBLE FAILURE BETWEEN UNITS
FAILURE BETWEEN UNITS IN OTHER SYSTEM	DOUBLE FAILURE BETWEEN UNITS
FAILURE IN OPPOSITE UNIT	FAILURE BETWEEN UNITS IN OWN SYSTEM
PERFECT STATE	FAILURE BETWEEN UNITS IN OWN SYSTEM

FIG.29

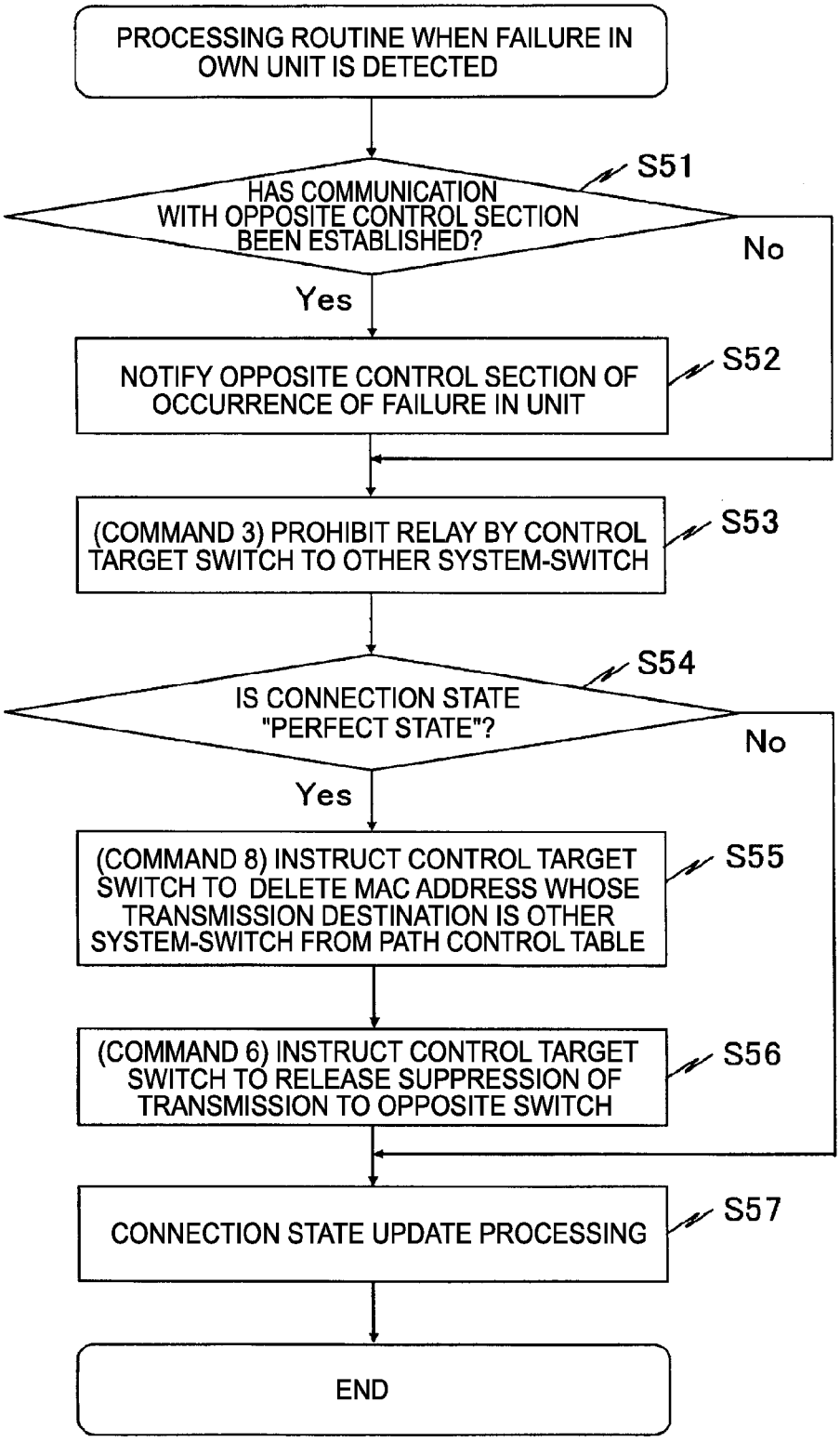

PROCESSING ROUTINE WHEN FAILURE IN OWN UNIT IS DETECTED
S51
HAS COMMUNICATION WITH OPPOSITE CONTROL SECTION BEEN ESTABLISHED?
No
Yes
NOTIFY OPPOSITE CONTROL SECTION OF OCCURRENCE OF FAILURE IN UNIT
S52
(COMMAND 3) PROHIBIT RELAY BY CONTROL TARGET SWITCH TO OTHER SYSTEM-SWITCH
S53
S54
IS CONNECTION STATE "PERFECT STATE"?
No
Yes
(COMMAND 8) INSTRUCT CONTROL TARGET SWITCH TO DELETE MAC ADDRESS WHOSE TRANSMISSION DESTINATION IS OTHER SYSTEM-SWITCH FROM PATH CONTROL TABLE
S55
(COMMAND 6) INSTRUCT CONTROL TARGET SWITCH TO RELEASE SUPPRESSION OF TRANSMISSION TO OPPOSITE SWITCH
S56
CONNECTION STATE UPDATE PROCESSING
S57
END

FIG.30

CONNECTION STATE BEFORE COMMUNICATION IS UNAVAILABLE	CONNECTION STATE AFTER COMMUNICATION IS UNAVAILABLE
DOUBLE FAILURE BETWEEN UNITS	INDEPENDENT STATE
FAILURE BETWEEN UNITS IN OWN SYSTEM	INDEPENDENT STATE
FAILURE BETWEEN UNITS IN OTHER SYSTEM AND FAILURE IN OPPOSITE UNIT	SIMPLEX STATE
FAILURE IN OPPOSITE UNIT	SIMPLEX STATE
FAILURE BETWEEN UNITS IN OTHER SYSTEM	FAILURE IN OWN UNIT
PERFECT STATE	FAILURE IN OWN UNIT

FIG.31

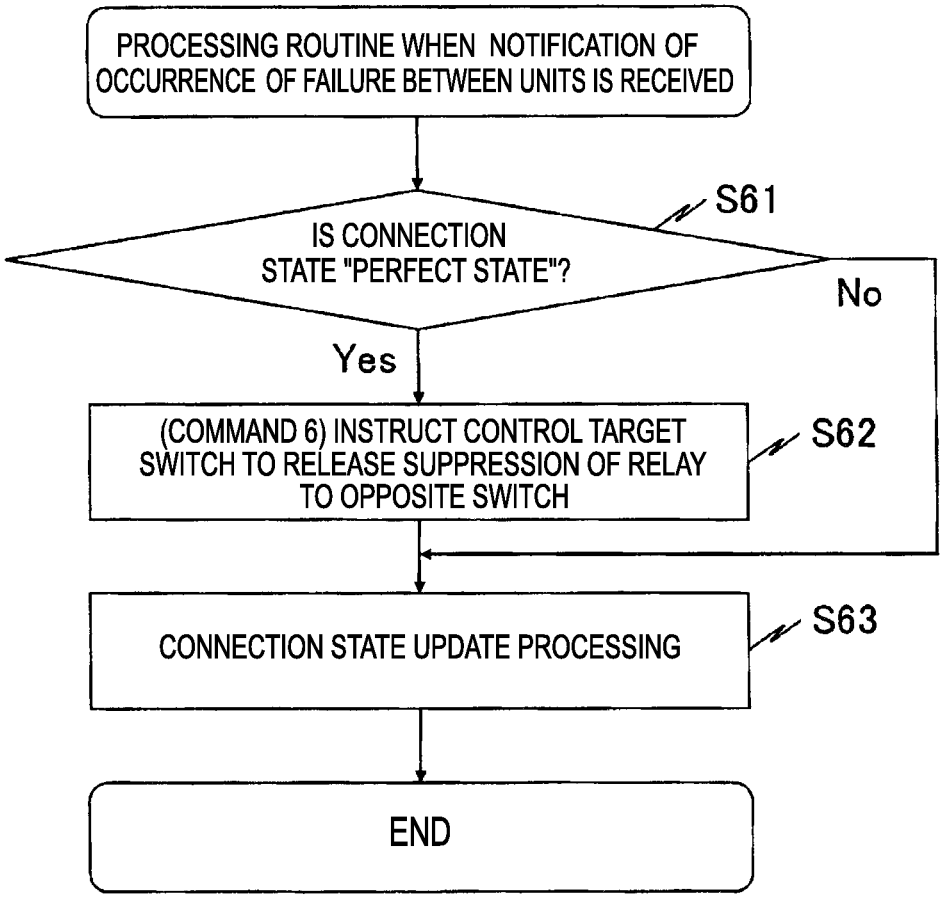

PROCESSING ROUTINE WHEN NOTIFICATION OF OCCURRENCE OF FAILURE BETWEEN UNITS IS RECEIVED
S61
IS CONNECTION STATE "PERFECT STATE"?
No
Yes
(COMMAND 6) INSTRUCT CONTROL TARGET SWITCH TO RELEASE SUPPRESSION OF RELAY TO OPPOSITE SWITCH
S62
CONNECTION STATE UPDATE PROCESSING
S63
END

FIG.32

CONNECTION STATE BEFORE NOTIFICATION IS RECEIVED	CONNECTION STATE AFTER NOTIFICATION IS RECEIVED
FAILURE BETWEEN UNITS IN OWN SYSTEM	DOUBLE FAILURE BETWEEN UNITS
FAILURE IN OPPOSITE UNIT	FAILURE BETWEEN UNITS IN OTHER SYSTEM AND FAILURE IN OPPOSITE UNIT
PERFECT STATE	FAILURE BETWEEN UNITS IN OTHER SYSTEM

FIG.33

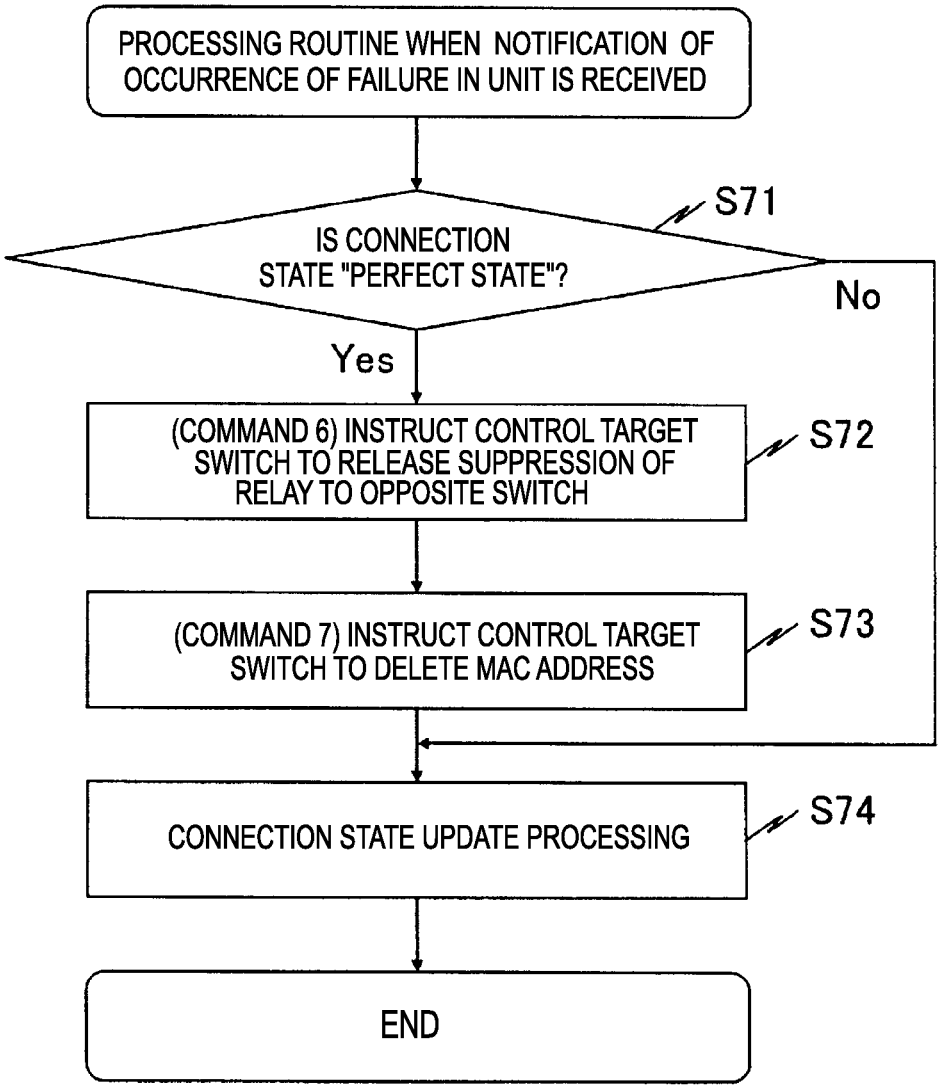

PROCESSING ROUTINE WHEN NOTIFICATION OF OCCURRENCE OF FAILURE IN UNIT IS RECEIVED
S71
IS CONNECTION STATE "PERFECT STATE"?
No
Yes
(COMMAND 6) INSTRUCT CONTROL TARGET SWITCH TO RELEASE SUPPRESSION OF RELAY TO OPPOSITE SWITCH
S72
(COMMAND 7) INSTRUCT CONTROL TARGET SWITCH TO DELETE MAC ADDRESS
S73
CONNECTION STATE UPDATE PROCESSING
S74
END

FIG.34

CONNECTION STATE BEFORE NOTIFICATION IS RECEIVED	CONNECTION STATE AFTER NOTIFICATION IS RECEIVED
FAILURE BETWEEN UNITS IN OWN SYSTEM	SIMPLEX STATE
FAILURE IN OPPOSITE UNIT	FAILURE BETWEEN UNITS IN OTHER SYSTEM AND FAILURE IN OPPOSITE UNIT
PERFECT STATE	FAILURE BETWEEN UNITS IN OTHER SYSTEM

FIG.35

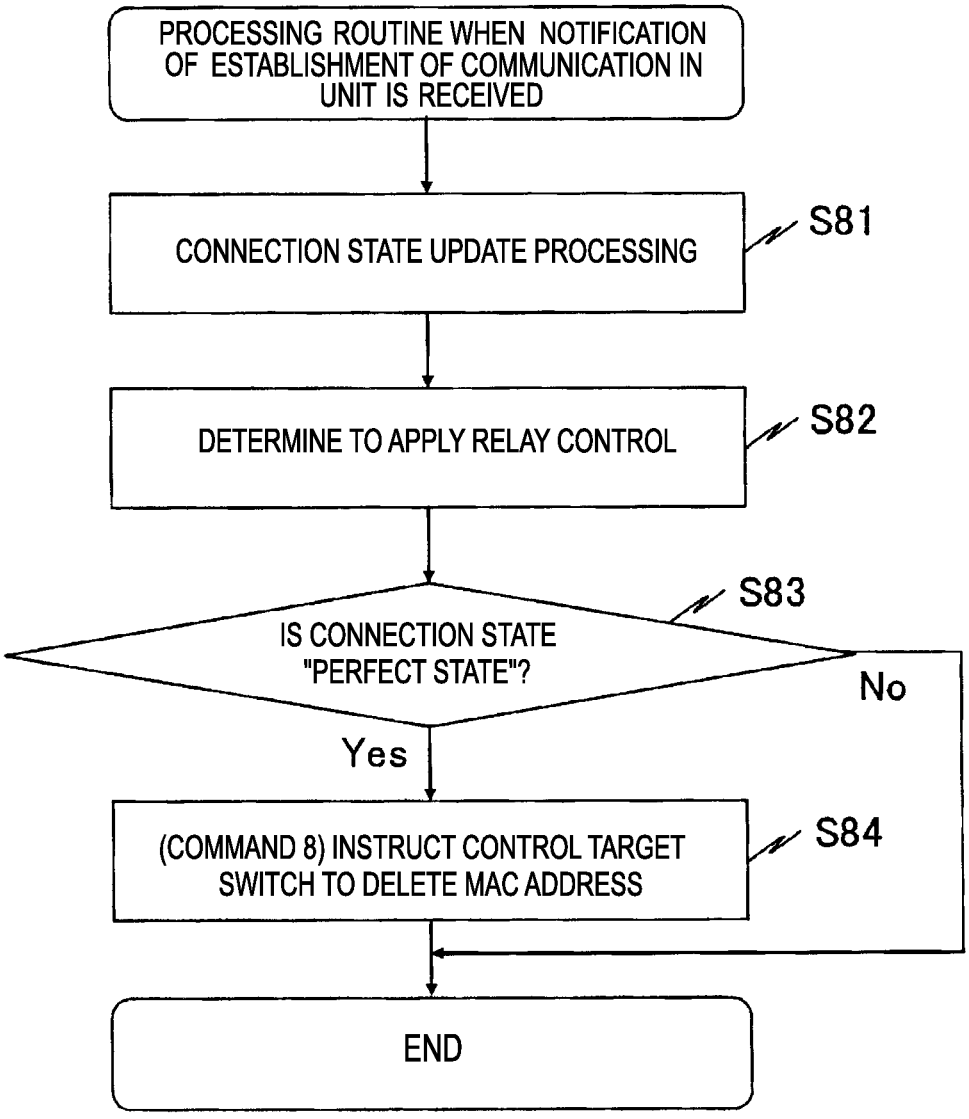

PROCESSING ROUTINE WHEN NOTIFICATION OF ESTABLISHMENT OF COMMUNICATION IN UNIT IS RECEIVED
CONNECTION STATE UPDATE PROCESSING
S81
DETERMINE TO APPLY RELAY CONTROL
S82
IS CONNECTION STATE "PERFECT STATE"?
S83
No
Yes
(COMMAND 8) INSTRUCT CONTROL TARGET SWITCH TO DELETE MAC ADDRESS
S84
END

FIG.36

CONNECTION STATE BEFORE NOTIFICATION IS RECEIVED	CONNECTION STATE AFTER NOTIFICATION IS RECEIVED
SIMPLEX STATE	FAILURE BETWEEN UNITS IN OWN SYSTEM
FAILURE BETWEEN UNITS IN OTHER SYSTEM AND FAILURE IN OPPOSITE UNIT	FAILURE IN OPPOSITE UNIT
FAILURE IN UNITS IN OTHER SYSTEM	PERFECT STATE

FIG.37

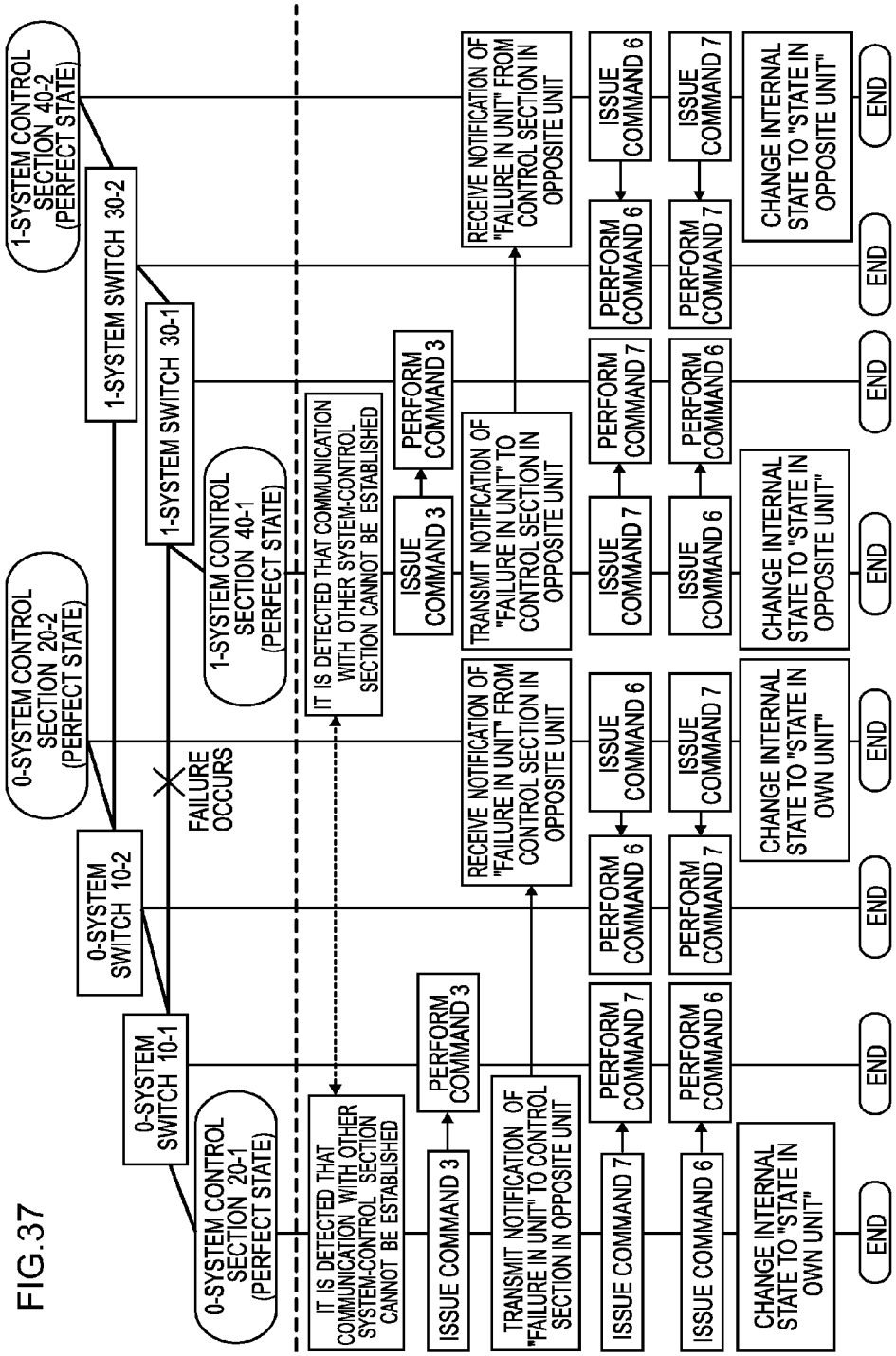

0-SYSTEM CONTROL SECTION 20-1 (PERFECT STATE)
0-SYSTEM SWITCH 10-1
0-SYSTEM SWITCH 10-2
0-SYSTEM CONTROL SECTION 20-2 (PERFECT STATE)
1-SYSTEM CONTROL SECTION 40-2 (PERFECT STATE)
1-SYSTEM SWITCH 30-2
1-SYSTEM SWITCH 30-1
1-SYSTEM CONTROL SECTION 40-1 (PERFECT STATE)
FAILURE OCCURS
IT IS DETECTED THAT COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION CANNOT BE ESTABLISHED
IT IS DETECTED THAT COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION CANNOT BE ESTABLISHED
ISSUE COMMAND 3
PERFORM COMMAND 3
ISSUE COMMAND 3
PERFORM COMMAND 3
TRANSMIT NOTIFICATION OF "FAILURE IN UNIT" TO CONTROL SECTION IN OPPOSITE UNIT
TRANSMIT NOTIFICATION OF "FAILURE IN UNIT" TO CONTROL SECTION IN OPPOSITE UNIT
RECEIVE NOTIFICATION OF "FAILURE IN UNIT" FROM CONTROL SECTION IN OPPOSITE UNIT
RECEIVE NOTIFICATION OF "FAILURE IN UNIT" FROM CONTROL SECTION IN OPPOSITE UNIT
ISSUE COMMAND 7
PERFORM COMMAND 7
ISSUE COMMAND 6
PERFORM COMMAND 6
ISSUE COMMAND 6
PERFORM COMMAND 6
ISSUE COMMAND 7
PERFORM COMMAND 7
ISSUE COMMAND 7
PERFORM COMMAND 7
ISSUE COMMAND 6
PERFORM COMMAND 6
ISSUE COMMAND 6
PERFORM COMMAND 6
ISSUE COMMAND 7
PERFORM COMMAND 7
CHANGE INTERNAL STATE TO "STATE IN OWN UNIT"
CHANGE INTERNAL STATE TO "STATE IN OPPOSITE UNIT"
CHANGE INTERNAL STATE TO "STATE IN OWN UNIT"
CHANGE INTERNAL STATE TO "STATE IN OPPOSITE UNIT"
END
END
END
END
END
END
END
END

FIG.38

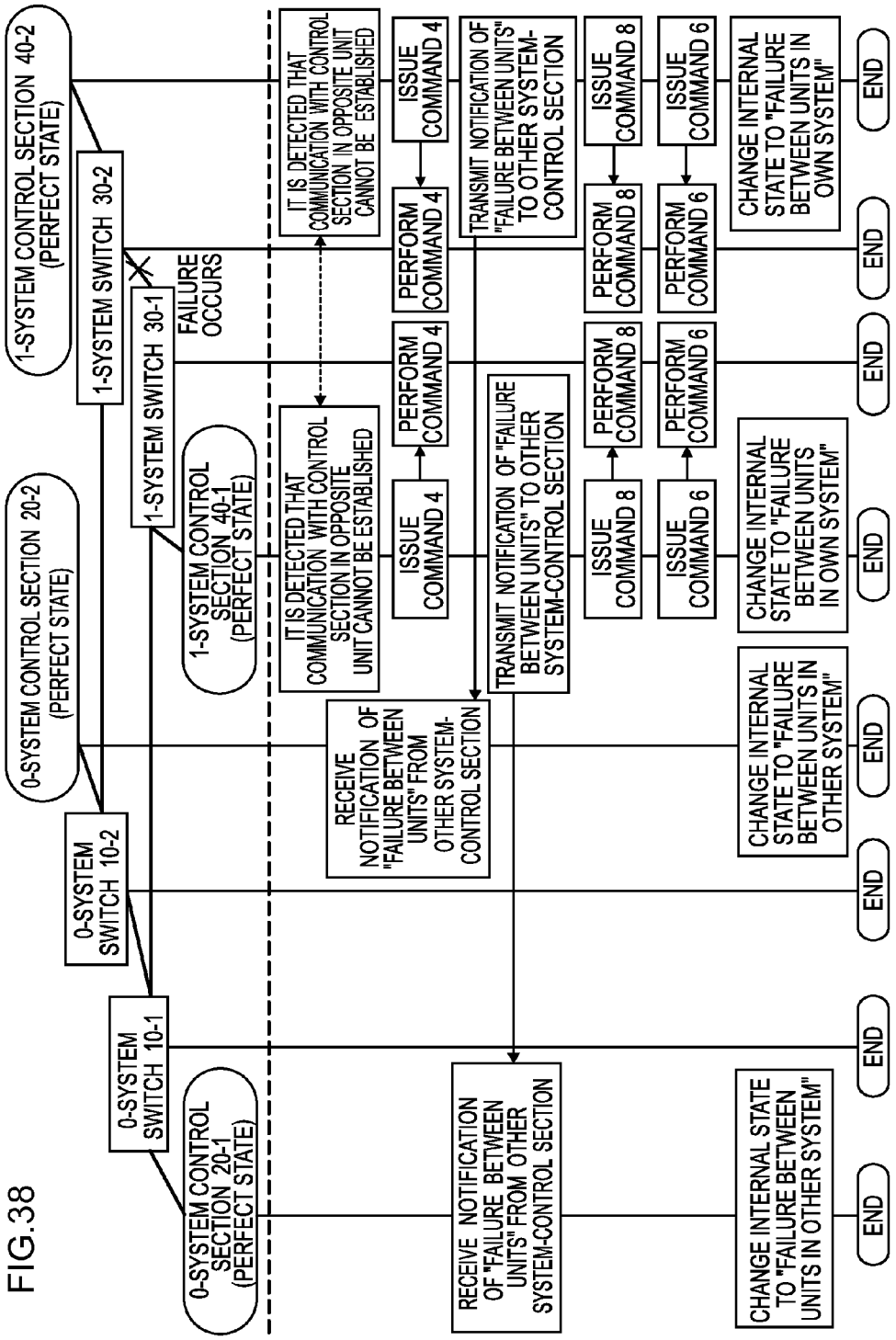
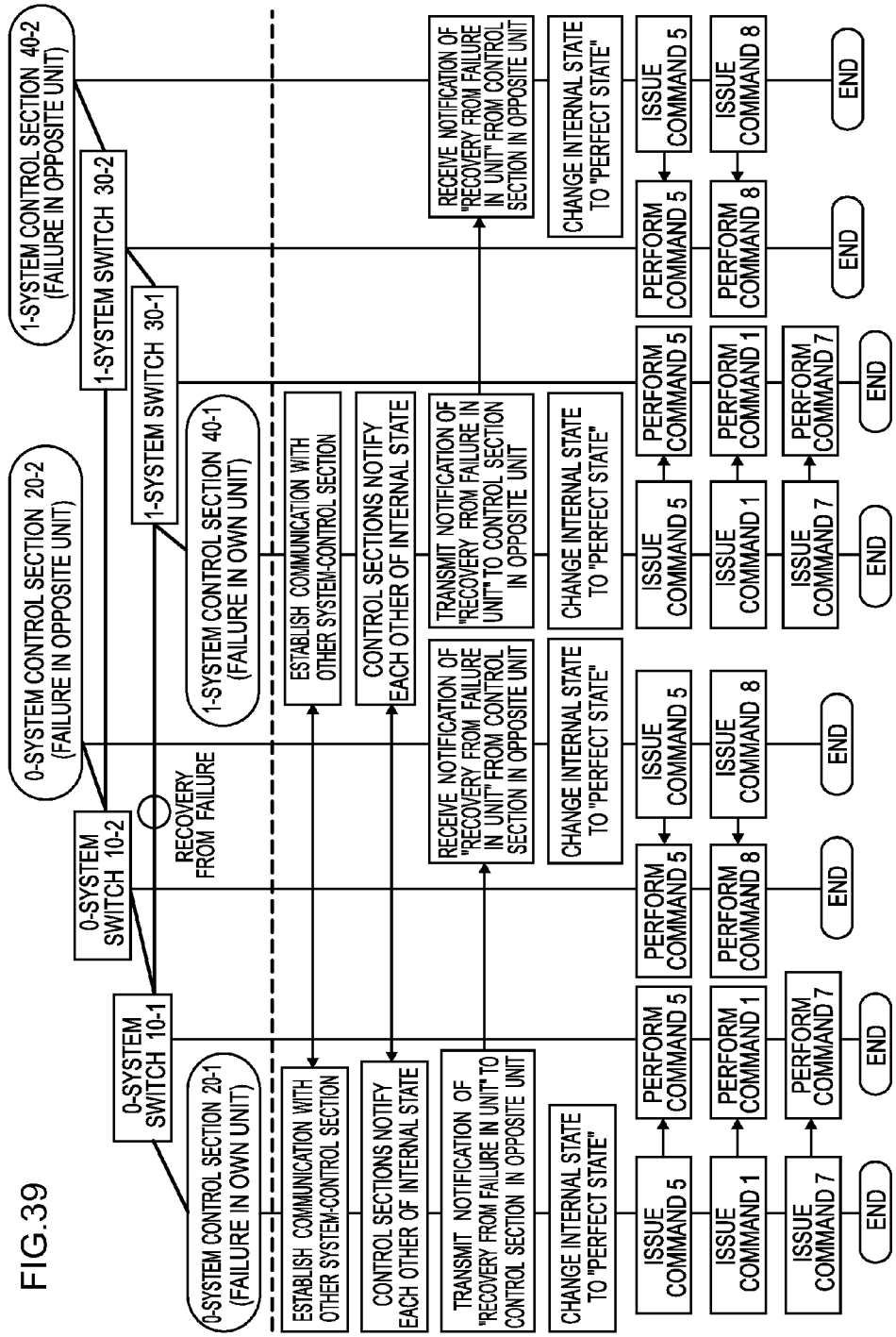

0-SYSTEM CONTROL SECTION 20-1 (PERFECT STATE)
0-SYSTEM SWITCH 10-1
0-SYSTEM SWITCH 10-2
0-SYSTEM CONTROL SECTION 20-2 (PERFECT STATE)
1-SYSTEM SWITCH 30-1
1-SYSTEM SWITCH 30-2
1-SYSTEM CONTROL SECTION 40-1 (PERFECT STATE)
1-SYSTEM CONTROL SECTION 40-2 (PERFECT STATE)
FAILURE OCCURS
IT IS DETECTED THAT COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT CANNOT BE ESTABLISHED
ISSUE COMMAND 4
PERFORM COMMAND 4
TRANSMIT NOTIFICATION OF "FAILURE BETWEEN UNITS" TO OTHER SYSTEM-CONTROL SECTION
ISSUE COMMAND 8
PERFORM COMMAND 8
ISSUE COMMAND 6
PERFORM COMMAND 6
CHANGE INTERNAL STATE TO "FAILURE BETWEEN UNITS IN OWN SYSTEM"
RECEIVE NOTIFICATION OF "FAILURE BETWEEN UNITS" FROM OTHER SYSTEM-CONTROL SECTION
CHANGE INTERNAL STATE TO "FAILURE BETWEEN UNITS IN OTHER SYSTEM"
END

FIG.39


0-SYSTEM CONTROL SECTION 20-1 (FAILURE IN OWN UNIT)
0-SYSTEM CONTROL SECTION 20-2 (FAILURE IN OPPOSITE UNIT)
1-SYSTEM CONTROL SECTION 40-1 (FAILURE IN OWN UNIT)
1-SYSTEM CONTROL SECTION 40-2 (FAILURE IN OPPOSITE UNIT)
0-SYSTEM SWITCH 10-1
0-SYSTEM SWITCH 10-2
1-SYSTEM SWITCH 30-1
1-SYSTEM SWITCH 30-2
RECOVERY FROM FAILURE
ESTABLISH COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION
CONTROL SECTIONS NOTIFY EACH OTHER OF INTERNAL STATE
TRANSMIT NOTIFICATION OF "RECOVERY FROM FAILURE IN UNIT" TO CONTROL SECTION IN OPPOSITE UNIT
RECEIVE NOTIFICATION OF "RECOVERY FROM FAILURE IN UNIT" FROM CONTROL SECTION IN OPPOSITE UNIT
CHANGE INTERNAL STATE TO "PERFECT STATE"
ISSUE COMMAND 5
ISSUE COMMAND 1
ISSUE COMMAND 7
ISSUE COMMAND 8
PERFORM COMMAND 5
PERFORM COMMAND 1
PERFORM COMMAND 7
PERFORM COMMAND 8
END

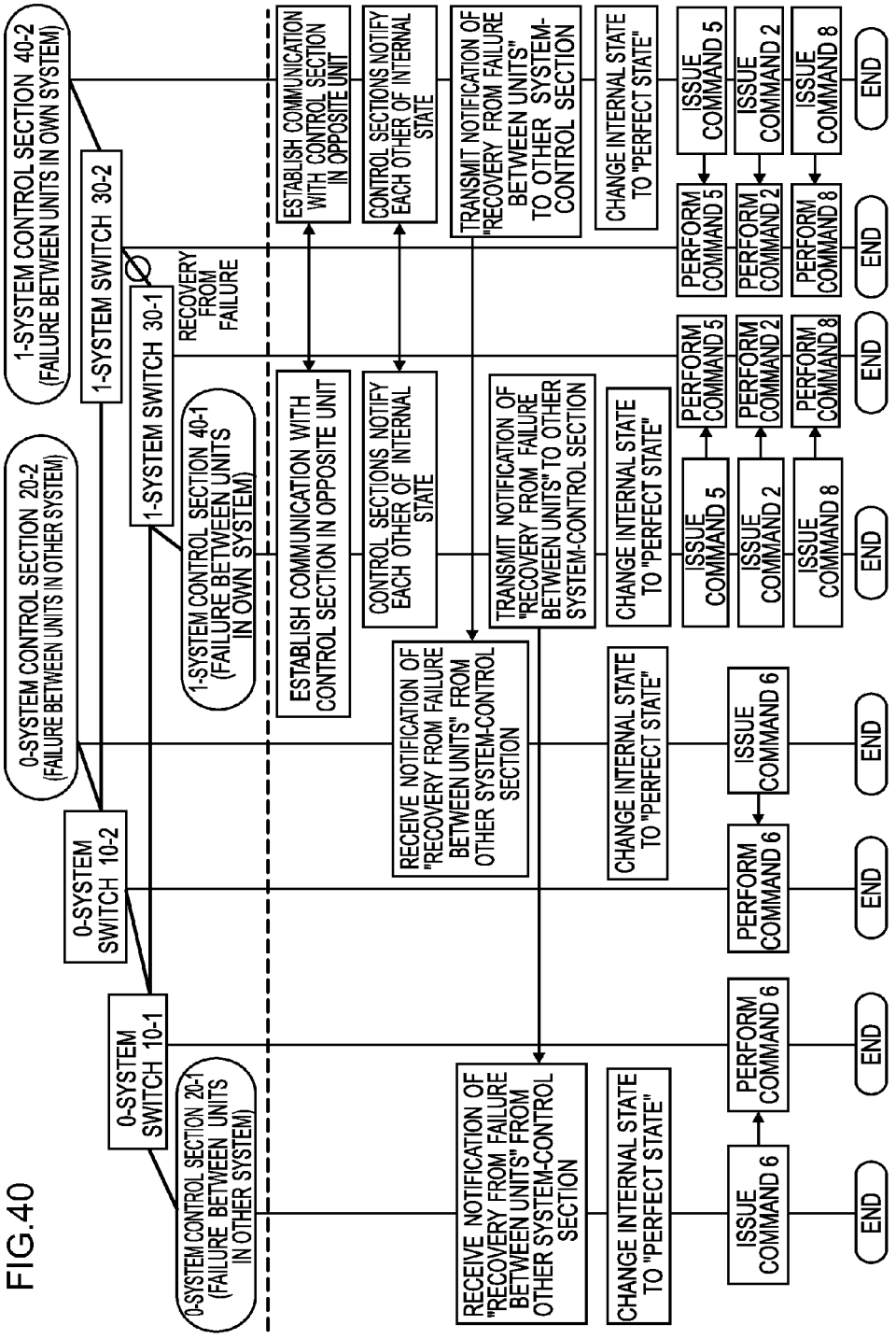

0-SYSTEM CONTROL SECTION 20-2 (FAILURE BETWEEN UNITS IN OTHER SYSTEM)
1-SYSTEM CONTROL SECTION 40-2 (FAILURE BETWEEN UNITS IN OWN SYSTEM)
0-SYSTEM SWITCH 10-2
1-SYSTEM SWITCH 30-2
0-SYSTEM SWITCH 10-1
1-SYSTEM SWITCH 30-1
RECOVERY FROM FAILURE
0-SYSTEM CONTROL SECTION 20-1 (FAILURE BETWEEN UNITS IN OTHER SYSTEM)
1-SYSTEM CONTROL SECTION 40-1 (FAILURE BETWEEN UNITS IN OWN SYSTEM)
ESTABLISH COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT
CONTROL SECTIONS NOTIFY EACH OTHER OF INTERNAL STATE
TRANSMIT NOTIFICATION OF "RECOVERY FROM FAILURE BETWEEN UNITS" TO OTHER SYSTEM-CONTROL SECTION
CHANGE INTERNAL STATE TO "PERFECT STATE"
ISSUE COMMAND 5
ISSUE COMMAND 2
ISSUE COMMAND 8
ISSUE COMMAND 6
PERFORM COMMAND 5
PERFORM COMMAND 2
PERFORM COMMAND 8
PERFORM COMMAND 6
RECEIVE NOTIFICATION OF "RECOVERY FROM FAILURE BETWEEN UNITS" FROM OTHER SYSTEM-CONTROL SECTION
END

FIG.40

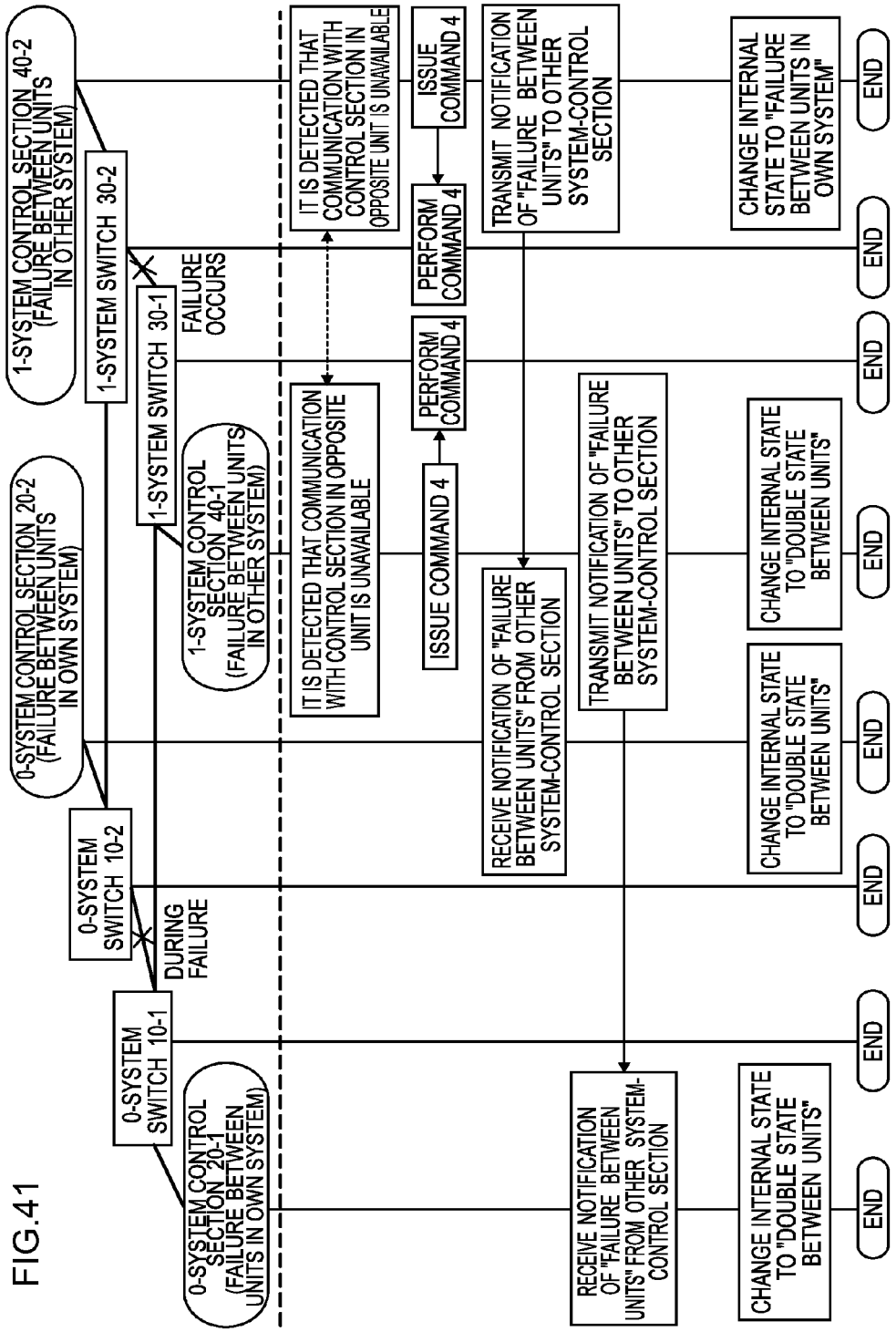

0-SYSTEM CONTROL SECTION 20-1 (FAILURE BETWEEN UNITS IN OWN SYSTEM)
0-SYSTEM CONTROL SECTION 20-2 (FAILURE BETWEEN UNITS IN OWN SYSTEM)
1-SYSTEM CONTROL SECTION 40-2 (FAILURE BETWEEN UNITS IN OTHER SYSTEM)
1-SYSTEM CONTROL SECTION 40-1 (FAILURE BETWEEN UNITS IN OTHER SYSTEM)
0-SYSTEM SWITCH 10-1
0-SYSTEM SWITCH 10-2
1-SYSTEM SWITCH 30-1
1-SYSTEM SWITCH 30-2
DURING FAILURE
FAILURE OCCURS
IT IS DETECTED THAT COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT IS UNAVAILABLE
IT IS DETECTED THAT COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT IS UNAVAILABLE
ISSUE COMMAND 4
ISSUE COMMAND 4
PERFORM COMMAND 4
PERFORM COMMAND 4
RECEIVE NOTIFICATION OF "FAILURE BETWEEN UNITS" FROM OTHER SYSTEM-CONTROL SECTION
TRANSMIT NOTIFICATION OF "FAILURE BETWEEN UNITS" TO OTHER SYSTEM-CONTROL SECTION
TRANSMIT NOTIFICATION OF "FAILURE BETWEEN UNITS" TO OTHER SYSTEM-CONTROL SECTION
RECEIVE NOTIFICATION OF "FAILURE BETWEEN UNITS" FROM OTHER SYSTEM-CONTROL SECTION
CHANGE INTERNAL STATE TO "DOUBLE STATE BETWEEN UNITS"
CHANGE INTERNAL STATE TO "DOUBLE STATE BETWEEN UNITS"
CHANGE INTERNAL STATE TO "DOUBLE STATE BETWEEN UNITS"
CHANGE INTERNAL STATE TO "FAILURE BETWEEN UNITS IN OWN SYSTEM"
END
END
END
END
END
END
END
END

FIG.41

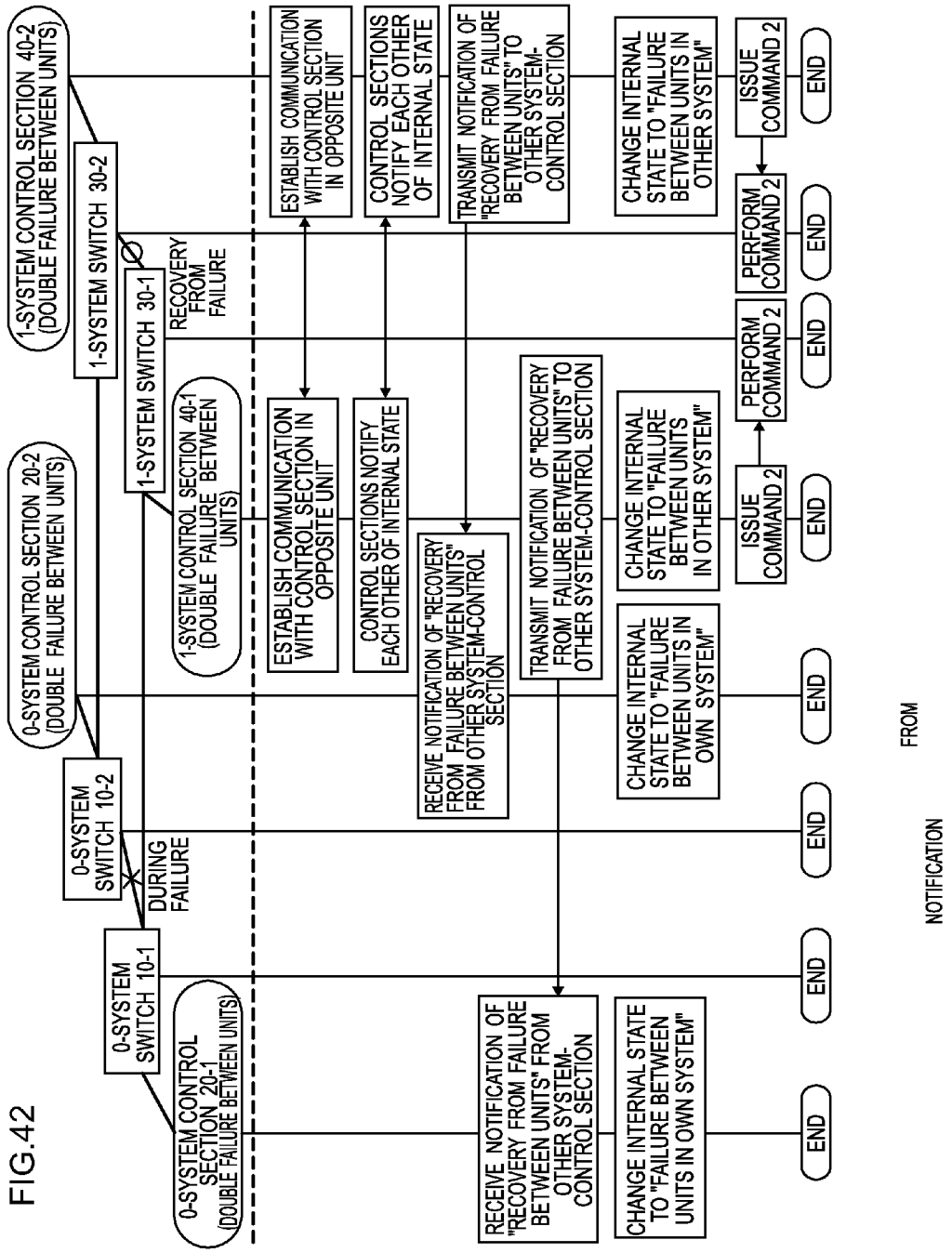

0-SYSTEM CONTROL SECTION 20-2 (DOUBLE FAILURE BETWEEN UNITS)
1-SYSTEM CONTROL SECTION 40-2 (DOUBLE FAILURE BETWEEN UNITS)
0-SYSTEM SWITCH 10-2
1-SYSTEM SWITCH 30-2
0-SYSTEM SWITCH 10-1
1-SYSTEM SWITCH 30-1
DURING FAILURE
RECOVERY FROM FAILURE
0-SYSTEM CONTROL SECTION 20-1 (DOUBLE FAILURE BETWEEN UNITS)
1-SYSTEM CONTROL SECTION 40-1 (DOUBLE FAILURE BETWEEN UNITS)
ESTABLISH COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT
CONTROL SECTIONS NOTIFY EACH OTHER OF INTERNAL STATE
RECEIVE NOTIFICATION OF "RECOVERY FROM FAILURE BETWEEN UNITS" FROM OTHER SYSTEM-CONTROL SECTION
TRANSMIT NOTIFICATION OF "RECOVERY FROM FAILURE BETWEEN UNITS" TO OTHER SYSTEM-CONTROL SECTION
CHANGE INTERNAL STATE TO "FAILURE BETWEEN UNITS IN OWN SYSTEM"
CHANGE INTERNAL STATE TO "FAILURE BETWEEN UNITS IN OTHER SYSTEM"
ISSUE COMMAND 2
PERFORM COMMAND 2
END
FROM NOTIFICATION

FIG.42

FIG.43

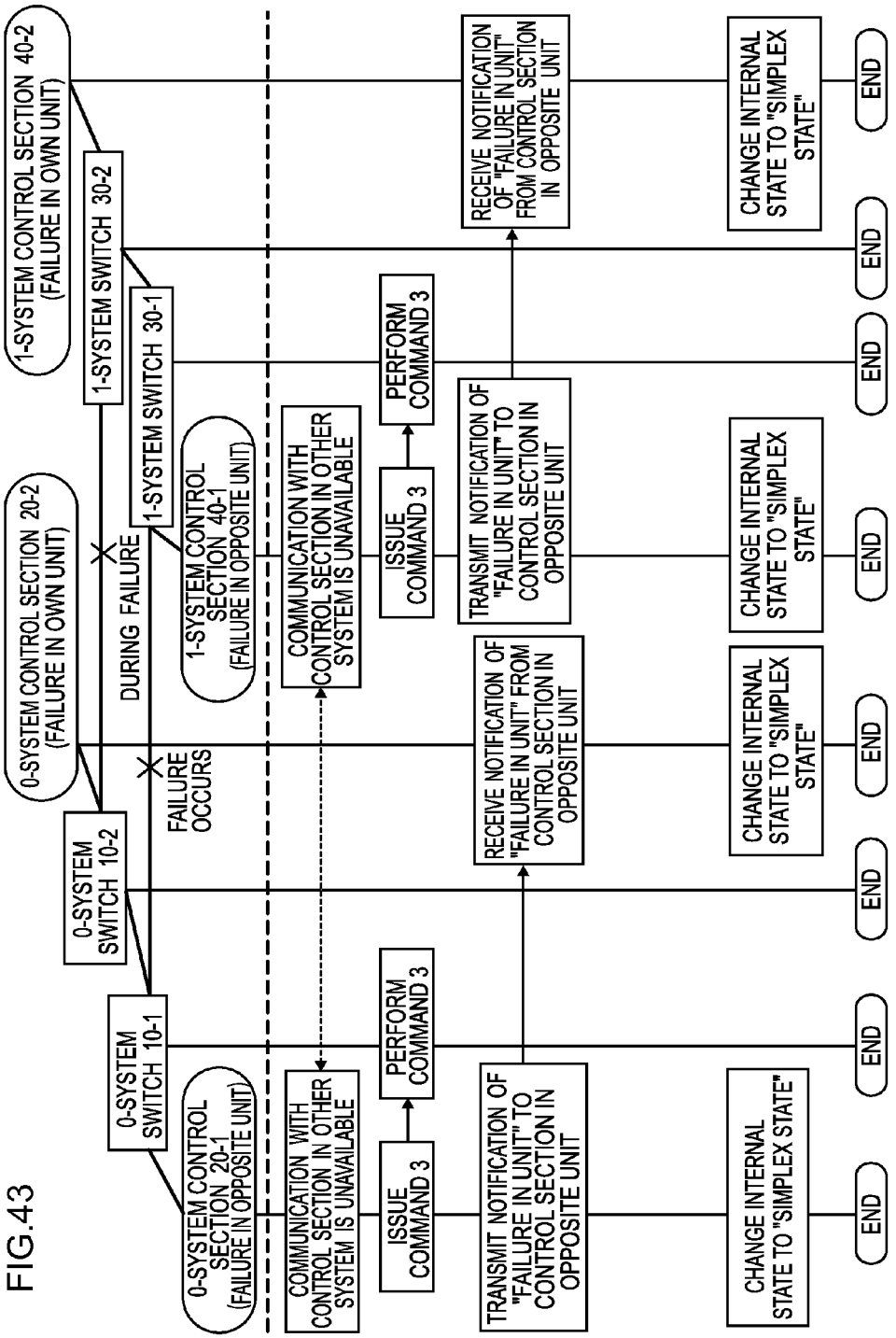
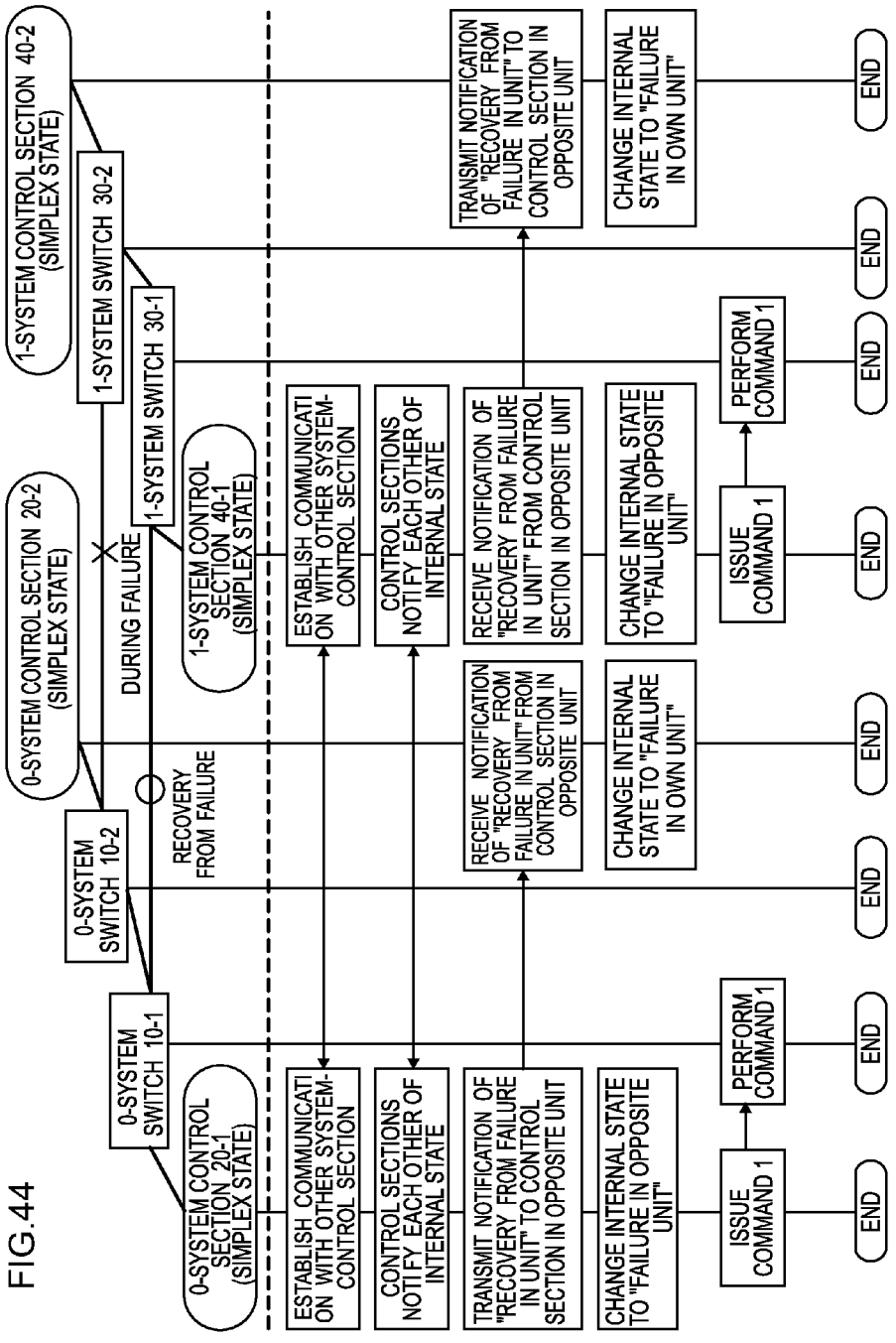

0-SYSTEM CONTROL SECTION 20-2 (FAILURE IN OWN UNIT)
1-SYSTEM CONTROL SECTION 40-2 (FAILURE IN OWN UNIT)
DURING FAILURE
FAILURE OCCURS
0-SYSTEM SWITCH 10-2
0-SYSTEM SWITCH 10-1
1-SYSTEM SWITCH 30-2
1-SYSTEM SWITCH 30-1
0-SYSTEM CONTROL SECTION 20-1 (FAILURE IN OPPOSITE UNIT)
1-SYSTEM CONTROL SECTION 40-1 (FAILURE IN OPPOSITE UNIT)
COMMUNICATION WITH CONTROL SECTION IN OTHER SYSTEM IS UNAVAILABLE
ISSUE COMMAND 3
PERFORM COMMAND 3
TRANSMIT NOTIFICATION OF "FAILURE IN UNIT" TO CONTROL SECTION IN OPPOSITE UNIT
RECEIVE NOTIFICATION OF "FAILURE IN UNIT" FROM CONTROL SECTION IN OPPOSITE UNIT
CHANGE INTERNAL STATE TO "SIMPLEX STATE"
END

FIG.44


0-SYSTEM CONTROL SECTION 20-1 (SIMPLEX STATE)
0-SYSTEM SWITCH 10-1
0-SYSTEM SWITCH 10-2
0-SYSTEM CONTROL SECTION 20-2 (SIMPLEX STATE)
1-SYSTEM CONTROL SECTION 40-2 (SIMPLEX STATE)
1-SYSTEM SWITCH 30-2
1-SYSTEM SWITCH 30-1
1-SYSTEM CONTROL SECTION 40-1 (SIMPLEX STATE)
DURING FAILURE
RECOVERY FROM FAILURE
ESTABLISH COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION
CONTROL SECTIONS NOTIFY EACH OTHER OF INTERNAL STATE
TRANSMIT NOTIFICATION OF "RECOVERY FROM FAILURE IN UNIT" TO CONTROL SECTION IN OPPOSITE UNIT
CHANGE INTERNAL STATE TO "FAILURE IN OPPOSITE UNIT"
ISSUE COMMAND 1
PERFORM COMMAND 1
END
RECEIVE NOTIFICATION OF "RECOVERY FROM FAILURE IN UNIT" FROM CONTROL SECTION IN OPPOSITE UNIT
CHANGE INTERNAL STATE TO "FAILURE IN OWN UNIT"
TRANSMIT NOTIFICATION OF "RECOVERY FROM FAILURE IN UNIT" TO CONTROL SECTION IN OPPOSITE UNIT
CHANGE INTERNAL STATE TO "FAILURE IN OWN UNIT"
OF "RECOVERY
FAILU

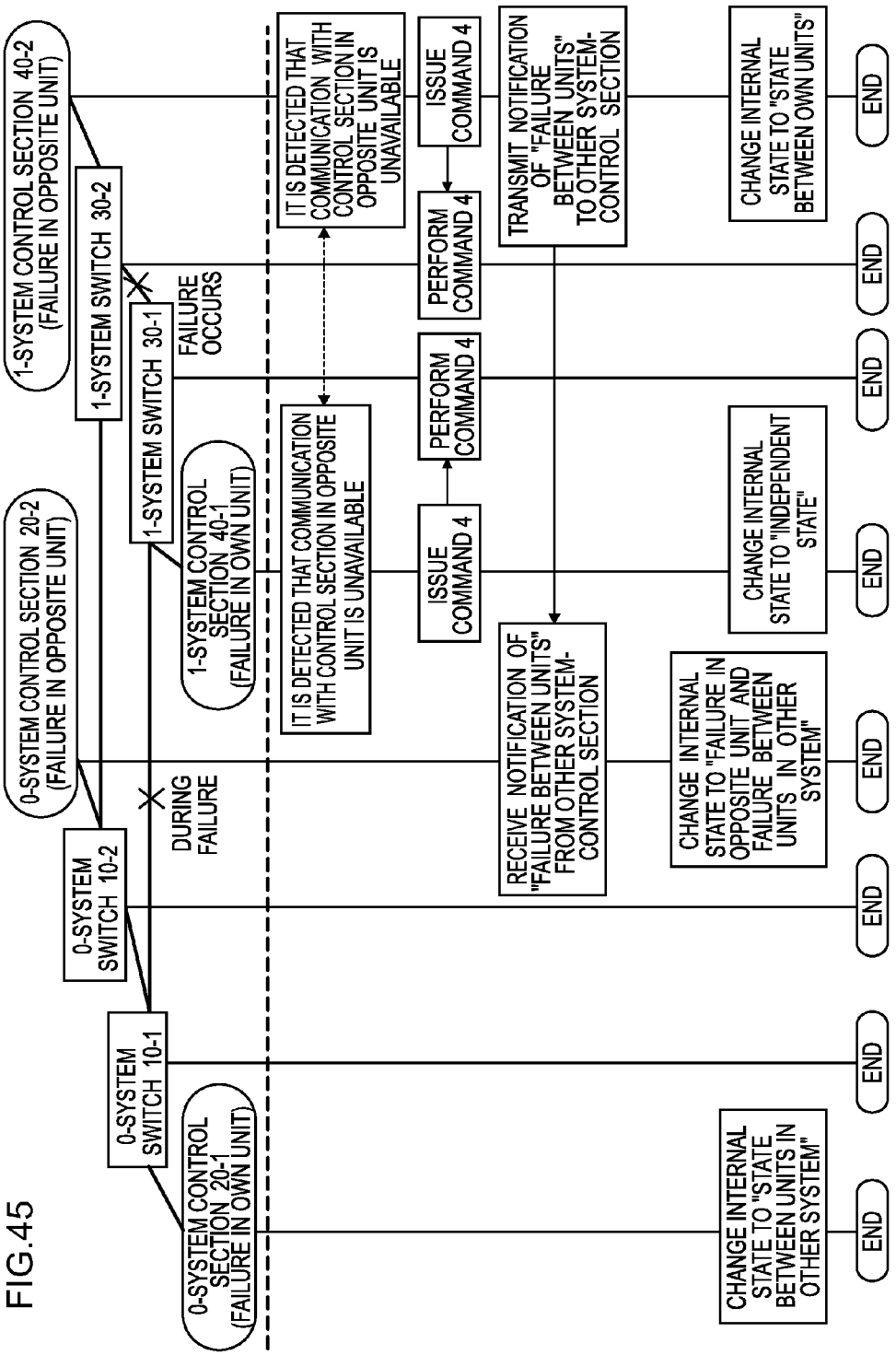

1-SYSTEM CONTROL SECTION 40-2 (FAILURE IN OPPOSITE UNIT)
1-SYSTEM SWITCH 30-2
1-SYSTEM SWITCH 30-1
FAILURE OCCURS
0-SYSTEM CONTROL SECTION 20-2 (FAILURE IN OPPOSITE UNIT)
1-SYSTEM CONTROL SECTION 40-1 (FAILURE IN OWN UNIT)
0-SYSTEM SWITCH 10-2
DURING FAILURE
0-SYSTEM SWITCH 10-1
0-SYSTEM CONTROL SECTION 20-1 (FAILURE IN OWN UNIT)
IT IS DETECTED THAT COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT IS UNAVAILABLE
IT IS DETECTED THAT COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT IS UNAVAILABLE
ISSUE COMMAND 4
PERFORM COMMAND 4
PERFORM COMMAND 4
TRANSMIT NOTIFICATION OF "FAILURE BETWEEN UNITS" TO OTHER SYSTEM-CONTROL SECTION
RECEIVE NOTIFICATION OF "FAILURE BETWEEN UNITS" FROM OTHER SYSTEM-CONTROL SECTION
CHANGE INTERNAL STATE TO "STATE BETWEEN OWN UNITS"
CHANGE INTERNAL STATE TO "INDEPENDENT STATE"
CHANGE INTERNAL STATE TO "FAILURE IN OPPOSITE UNIT AND FAILURE BETWEEN UNITS IN OTHER SYSTEM"
CHANGE INTERNAL STATE TO "STATE BETWEEN UNITS IN OTHER SYSTEM"
END
END
END
END
END
END
END

FIG.45

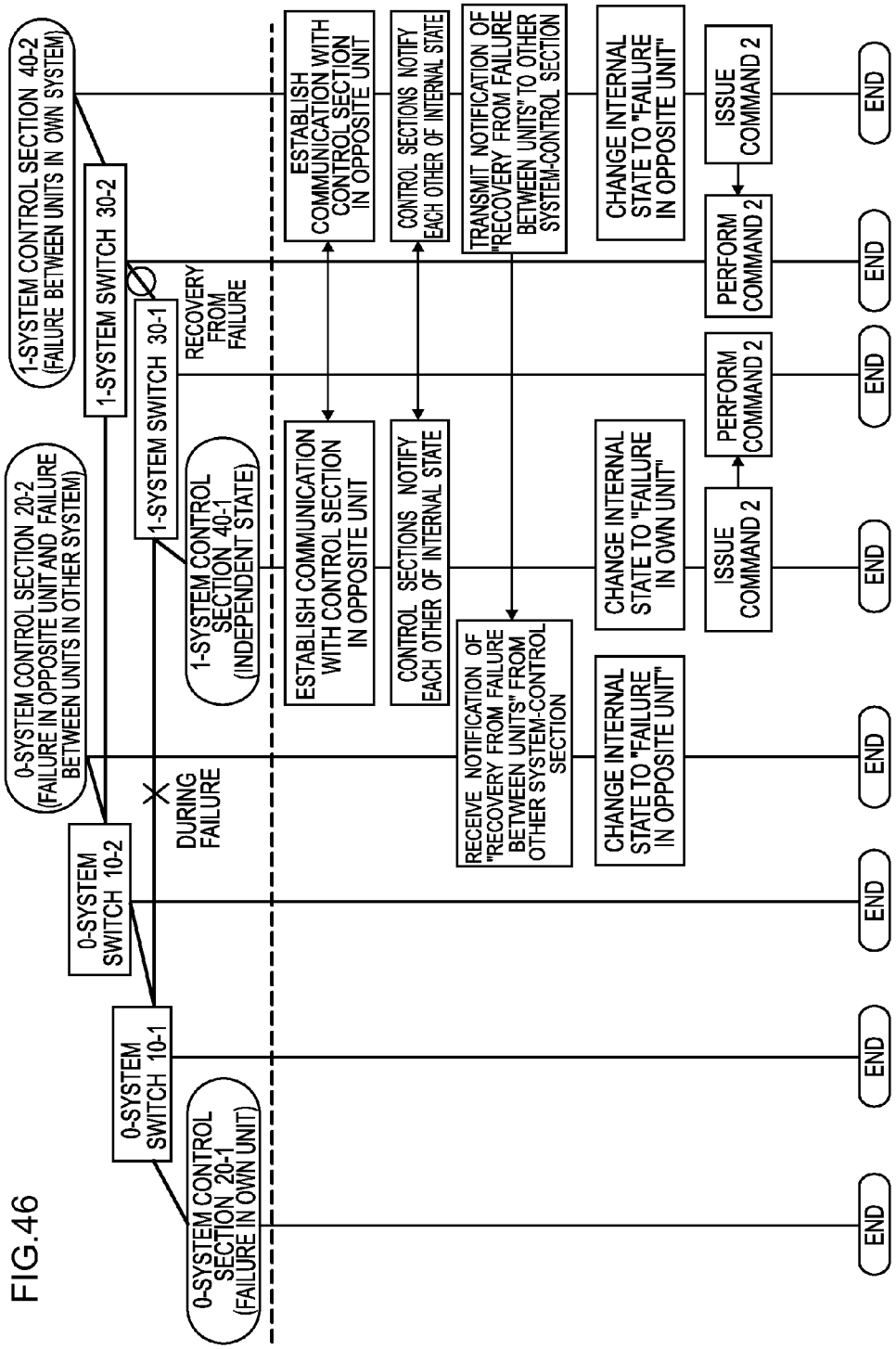

0-SYSTEM CONTROL SECTION 20-1 (FAILURE IN OWN UNIT)
0-SYSTEM SWITCH 10-1
0-SYSTEM SWITCH 10-2
0-SYSTEM CONTROL SECTION 20-2 (FAILURE IN OPPOSITE UNIT AND FAILURE BETWEEN UNITS IN OTHER SYSTEM)
1-SYSTEM CONTROL SECTION 40-1 (INDEPENDENT STATE)
1-SYSTEM SWITCH 30-1
1-SYSTEM SWITCH 30-2
1-SYSTEM CONTROL SECTION 40-2 (FAILURE BETWEEN UNITS IN OWN SYSTEM)
DURING FAILURE
RECOVERY FROM FAILURE
ESTABLISH COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT
CONTROL SECTIONS NOTIFY EACH OTHER OF INTERNAL STATE
RECEIVE NOTIFICATION OF "RECOVERY FROM FAILURE BETWEEN UNITS" FROM OTHER SYSTEM-CONTROL SECTION
TRANSMIT NOTIFICATION OF "RECOVERY FROM FAILURE BETWEEN UNITS" TO OTHER SYSTEM-CONTROL SECTION
CHANGE INTERNAL STATE TO "FAILURE IN OPPOSITE UNIT"
CHANGE INTERNAL STATE TO "FAILURE IN OWN UNIT"
ISSUE COMMAND 2
PERFORM COMMAND 2
END

FIG.46

FIG.47

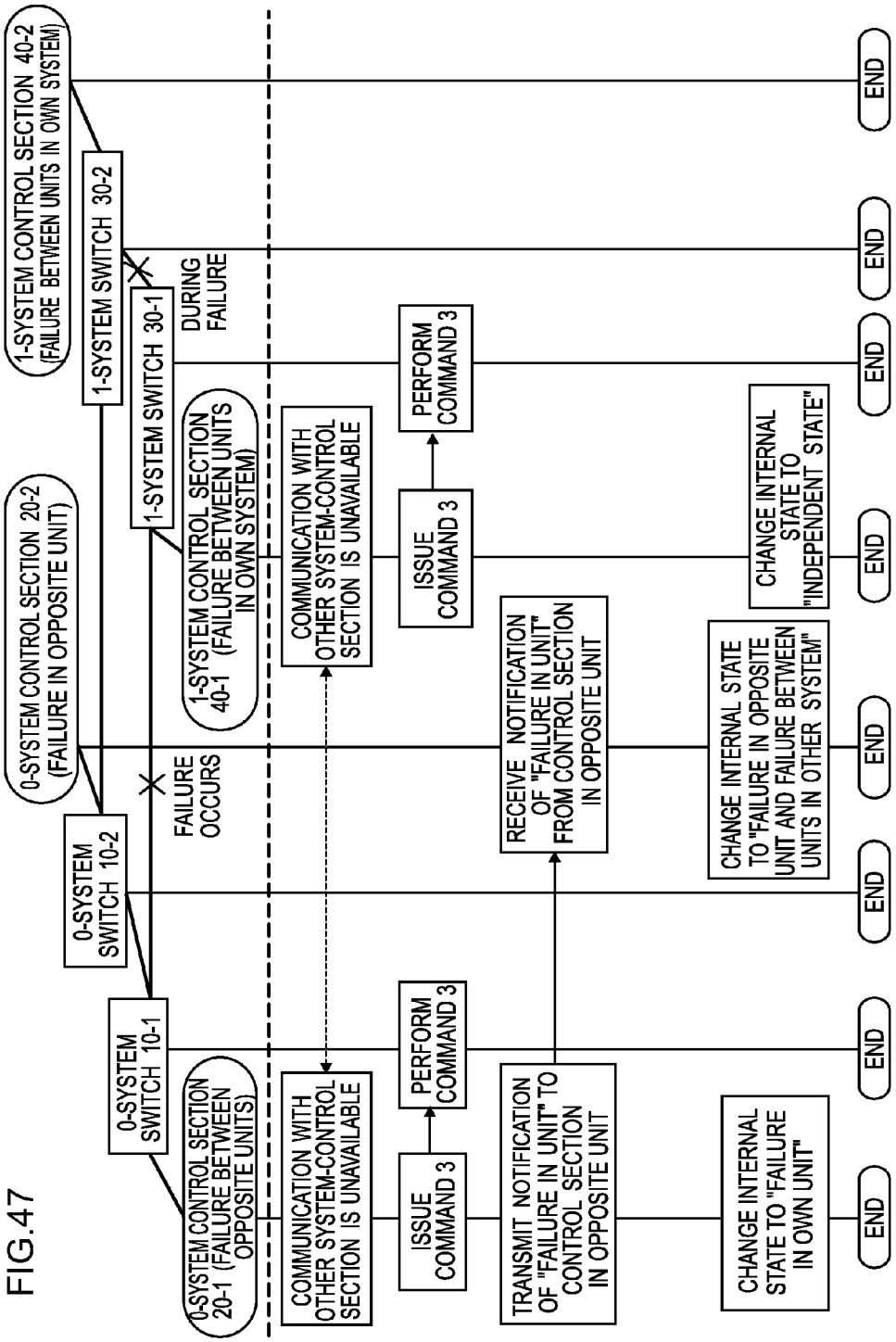

0-SYSTEM CONTROL SECTION 20-1 (FAILURE BETWEEN OPPOSITE UNITS)
0-SYSTEM SWITCH 10-1
0-SYSTEM SWITCH 10-2
0-SYSTEM CONTROL SECTION 20-2 (FAILURE IN OPPOSITE UNIT)
1-SYSTEM CONTROL SECTION 40-2 (FAILURE BETWEEN UNITS IN OWN SYSTEM)
1-SYSTEM SWITCH 30-2
1-SYSTEM SWITCH 30-1
1-SYSTEM CONTROL SECTION 40-1 (FAILURE BETWEEN UNITS IN OWN SYSTEM)
FAILURE OCCURS
DURING FAILURE
COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION IS UNAVAILABLE
ISSUE COMMAND 3
PERFORM COMMAND 3
TRANSMIT NOTIFICATION OF "FAILURE IN UNIT" TO CONTROL SECTION IN OPPOSITE UNIT
RECEIVE NOTIFICATION OF "FAILURE IN UNIT" FROM CONTROL SECTION IN OPPOSITE UNIT
CHANGE INTERNAL STATE TO "FAILURE IN OPPOSITE UNIT AND FAILURE BETWEEN UNITS IN OTHER SYSTEM"
CHANGE INTERNAL STATE TO "INDEPENDENT STATE"
CHANGE INTERNAL STATE TO "FAILURE IN OWN UNIT"
END

FIG.48

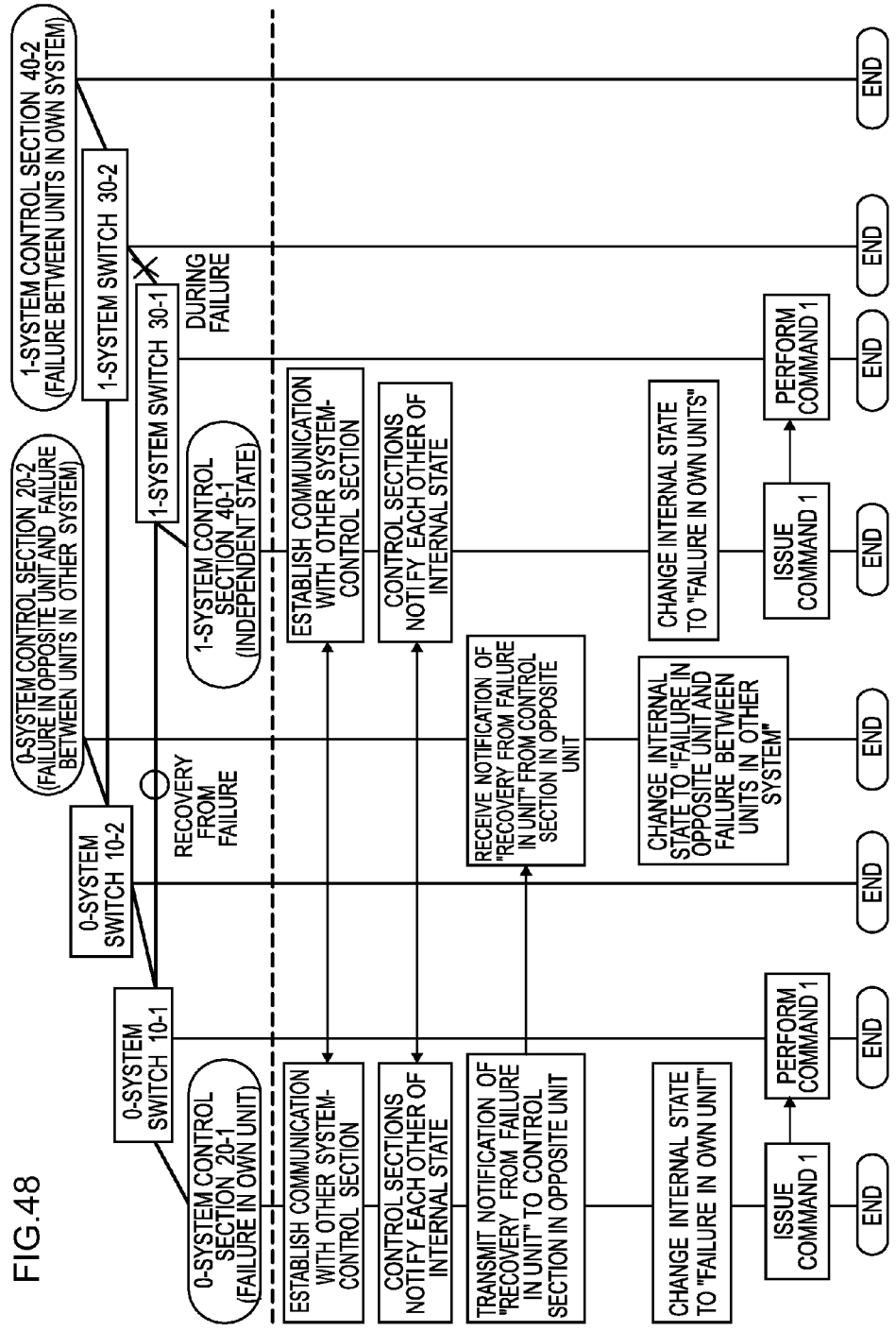

0-SYSTEM CONTROL SECTION 20-1 (FAILURE IN OWN UNIT)
0-SYSTEM SWITCH 10-1
0-SYSTEM SWITCH 10-2
0-SYSTEM CONTROL SECTION 20-2 (FAILURE IN OPPOSITE UNIT AND FAILURE BETWEEN UNITS IN OTHER SYSTEM)
1-SYSTEM CONTROL SECTION 40-2 (FAILURE BETWEEN UNITS IN OWN SYSTEM)
1-SYSTEM SWITCH 30-1
1-SYSTEM SWITCH 30-2
1-SYSTEM CONTROL SECTION 40-1 (INDEPENDENT STATE)
DURING FAILURE
RECOVERY FROM FAILURE
ESTABLISH COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION
CONTROL SECTIONS NOTIFY EACH OTHER OF INTERNAL STATE
TRANSMIT NOTIFICATION OF "RECOVERY FROM FAILURE IN UNIT" TO CONTROL SECTION IN OPPOSITE UNIT
CHANGE INTERNAL STATE TO "FAILURE IN OWN UNIT"
ISSUE COMMAND 1
PERFORM COMMAND 1
END
RECEIVE NOTIFICATION OF "RECOVERY FROM FAILURE IN UNIT" FROM CONTROL SECTION IN OPPOSITE UNIT
CHANGE INTERNAL STATE TO "FAILURE IN OPPOSITE UNIT AND FAILURE BETWEEN UNITS IN OTHER SYSTEM"
CHANGE INTERNAL STATE TO "FAILURE IN OWN UNITS"

FIG.49

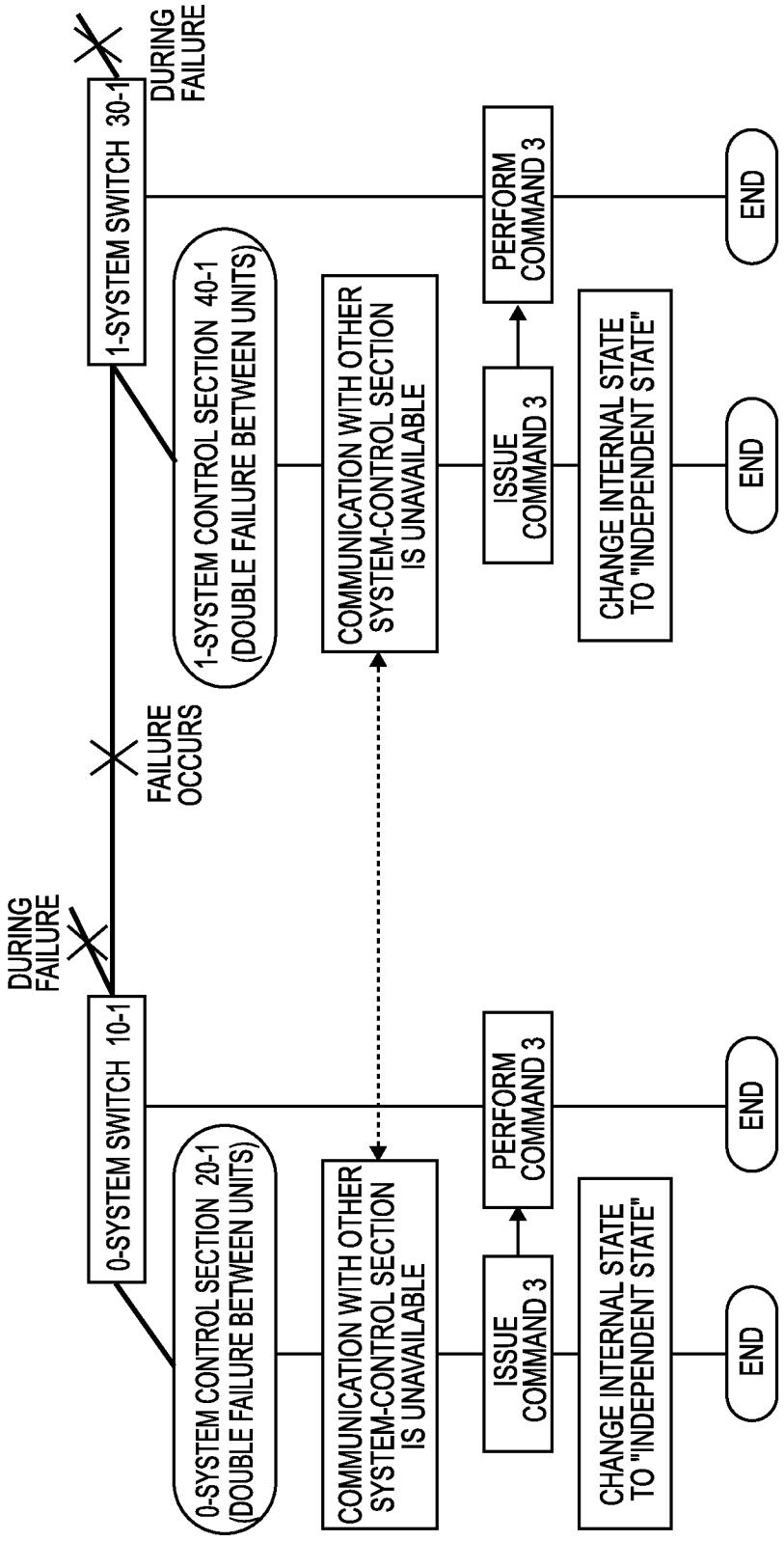

DURING FAILURE
0-SYSTEM SWITCH 10-1
FAILURE OCCURS
DURING FAILURE
1-SYSTEM SWITCH 30-1
0-SYSTEM CONTROL SECTION 20-1 (DOUBLE FAILURE BETWEEN UNITS)
1-SYSTEM CONTROL SECTION 40-1 (DOUBLE FAILURE BETWEEN UNITS)
COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION IS UNAVAILABLE
COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION IS UNAVAILABLE
ISSUE COMMAND 3
ISSUE COMMAND 3
PERFORM COMMAND 3
PERFORM COMMAND 3
CHANGE INTERNAL STATE TO "INDEPENDENT STATE"
CHANGE INTERNAL STATE TO "INDEPENDENT STATE"
END
END
END
END

FIG.50

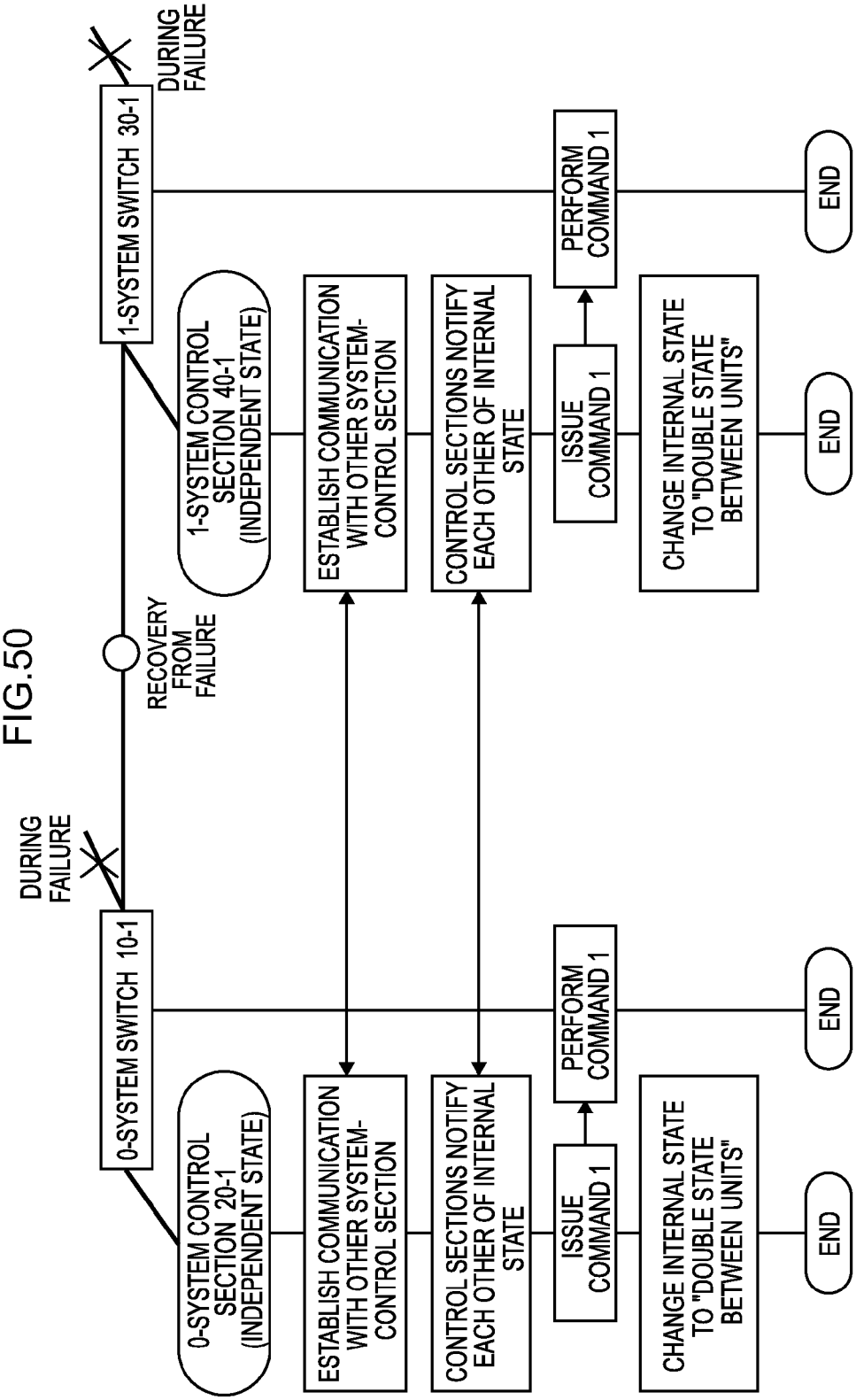

DURING FAILURE
0-SYSTEM SWITCH 10-1
RECOVERY FROM FAILURE
DURING FAILURE
1-SYSTEM SWITCH 30-1
0-SYSTEM CONTROL SECTION 20-1 (INDEPENDENT STATE)
1-SYSTEM CONTROL SECTION 40-1 (INDEPENDENT STATE)
ESTABLISH COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION
ESTABLISH COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION
CONTROL SECTIONS NOTIFY EACH OTHER OF INTERNAL STATE
CONTROL SECTIONS NOTIFY EACH OTHER OF INTERNAL STATE
ISSUE COMMAND 1
ISSUE COMMAND 1
PERFORM COMMAND 1
PERFORM COMMAND 1
CHANGE INTERNAL STATE TO "DOUBLE STATE BETWEEN UNITS"
CHANGE INTERNAL STATE TO "DOUBLE STATE BETWEEN UNITS"
END
END
END
END

FIG.51

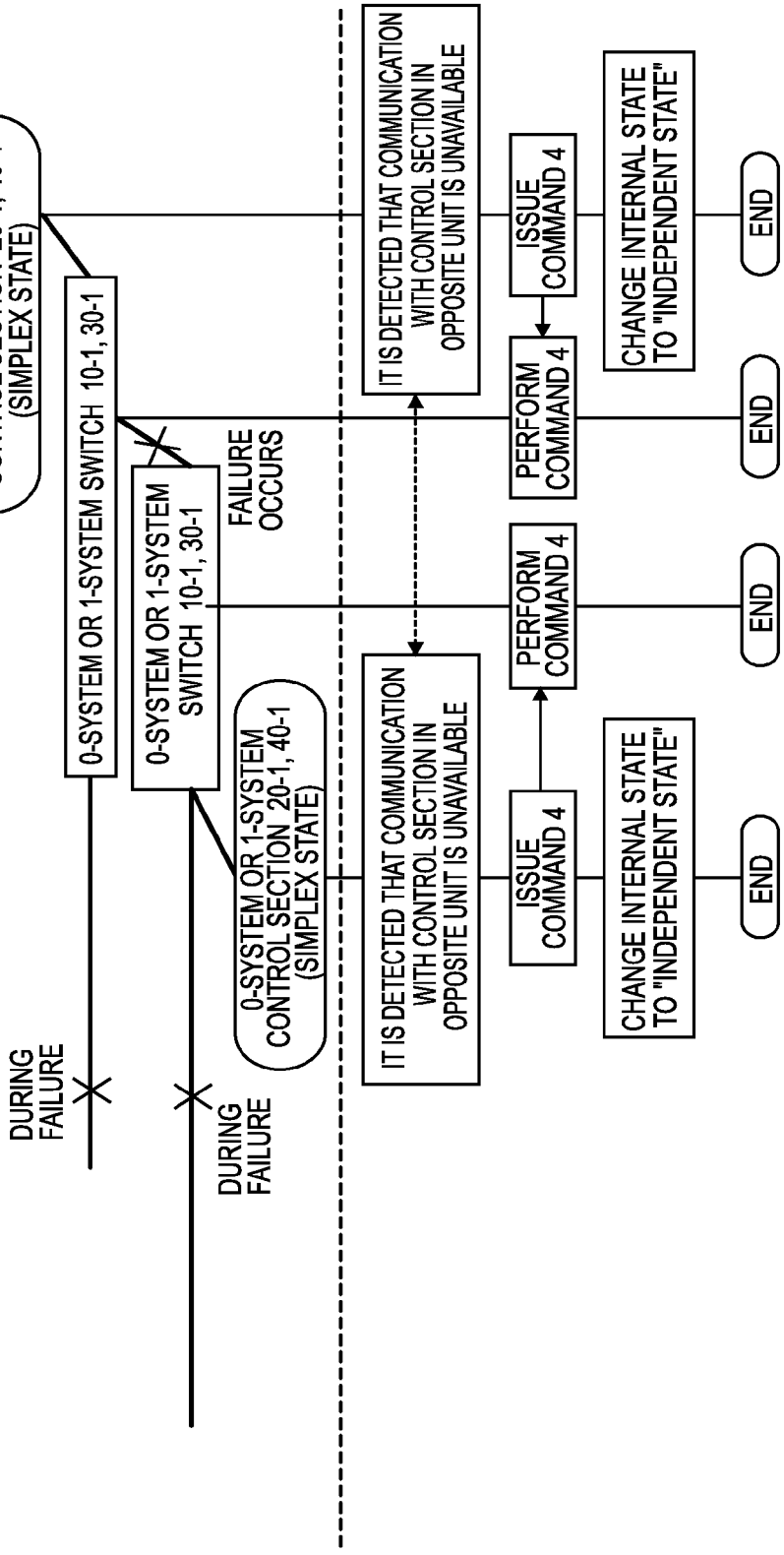
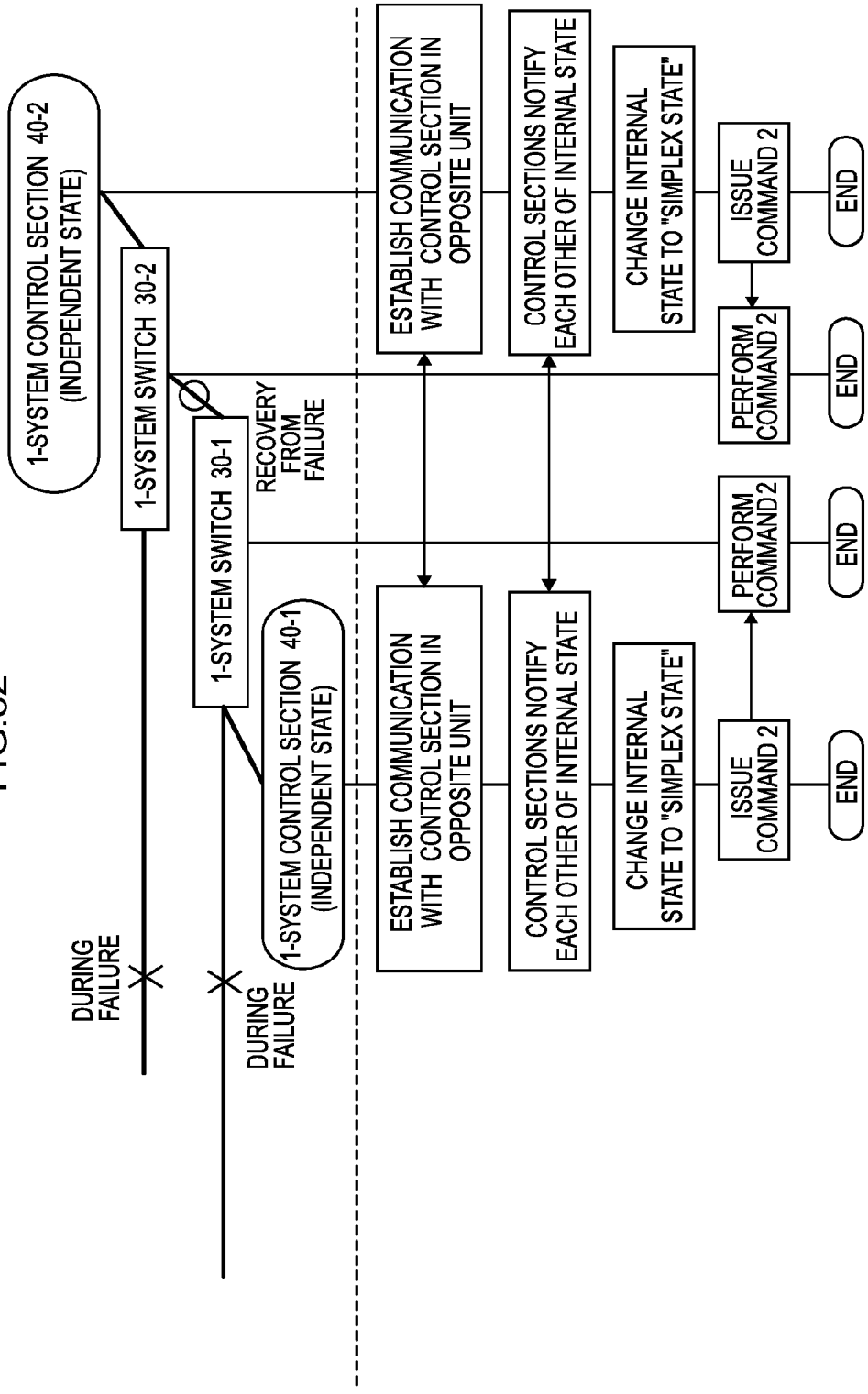

0-SYSTEM OR 1-SYSTEM CONTROL SECTION 20-1, 40-1 (SIMPLEX STATE)
0-SYSTEM OR 1-SYSTEM SWITCH 10-1, 30-1
0-SYSTEM OR 1-SYSTEM SWITCH 10-1, 30-1
FAILURE OCCURS
0-SYSTEM OR 1-SYSTEM CONTROL SECTION 20-1, 40-1 (SIMPLEX STATE)
DURING FAILURE
DURING FAILURE
IT IS DETECTED THAT COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT IS UNAVAILABLE
IT IS DETECTED THAT COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT IS UNAVAILABLE
ISSUE COMMAND 4
ISSUE COMMAND 4
PERFORM COMMAND 4
PERFORM COMMAND 4
CHANGE INTERNAL STATE TO "INDEPENDENT STATE"
CHANGE INTERNAL STATE TO "INDEPENDENT STATE"
END
END
END
END

FIG.52


1-SYSTEM CONTROL SECTION 40-2
(INDEPENDENT STATE)
1-SYSTEM SWITCH 30-2
1-SYSTEM SWITCH 30-1
RECOVERY FROM FAILURE
1-SYSTEM CONTROL SECTION 40-1
(INDEPENDENT STATE)
DURING FAILURE
DURING FAILURE
ESTABLISH COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT
CONTROL SECTIONS NOTIFY EACH OTHER OF INTERNAL STATE
CHANGE INTERNAL STATE TO "SIMPLEX STATE"
ISSUE COMMAND 2
PERFORM COMMAND 2
END
ESTABLISH COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT
CONTROL SECTIONS NOTIFY EACH OTHER OF INTERNAL STATE
CHANGE INTERNAL STATE TO "SIMPLEX STATE"
ISSUE COMMAND 2
PERFORM COMMAND 2
END

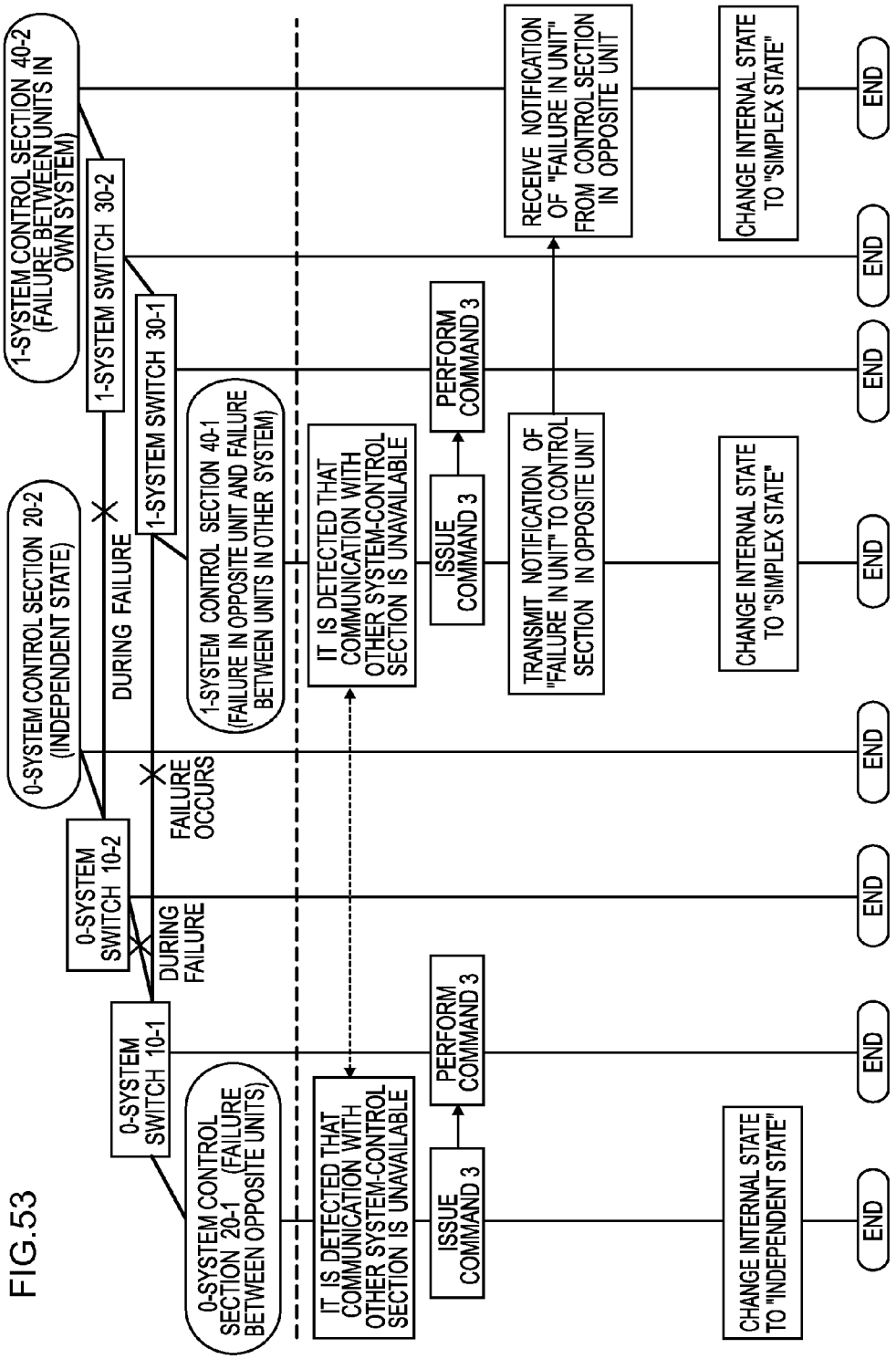
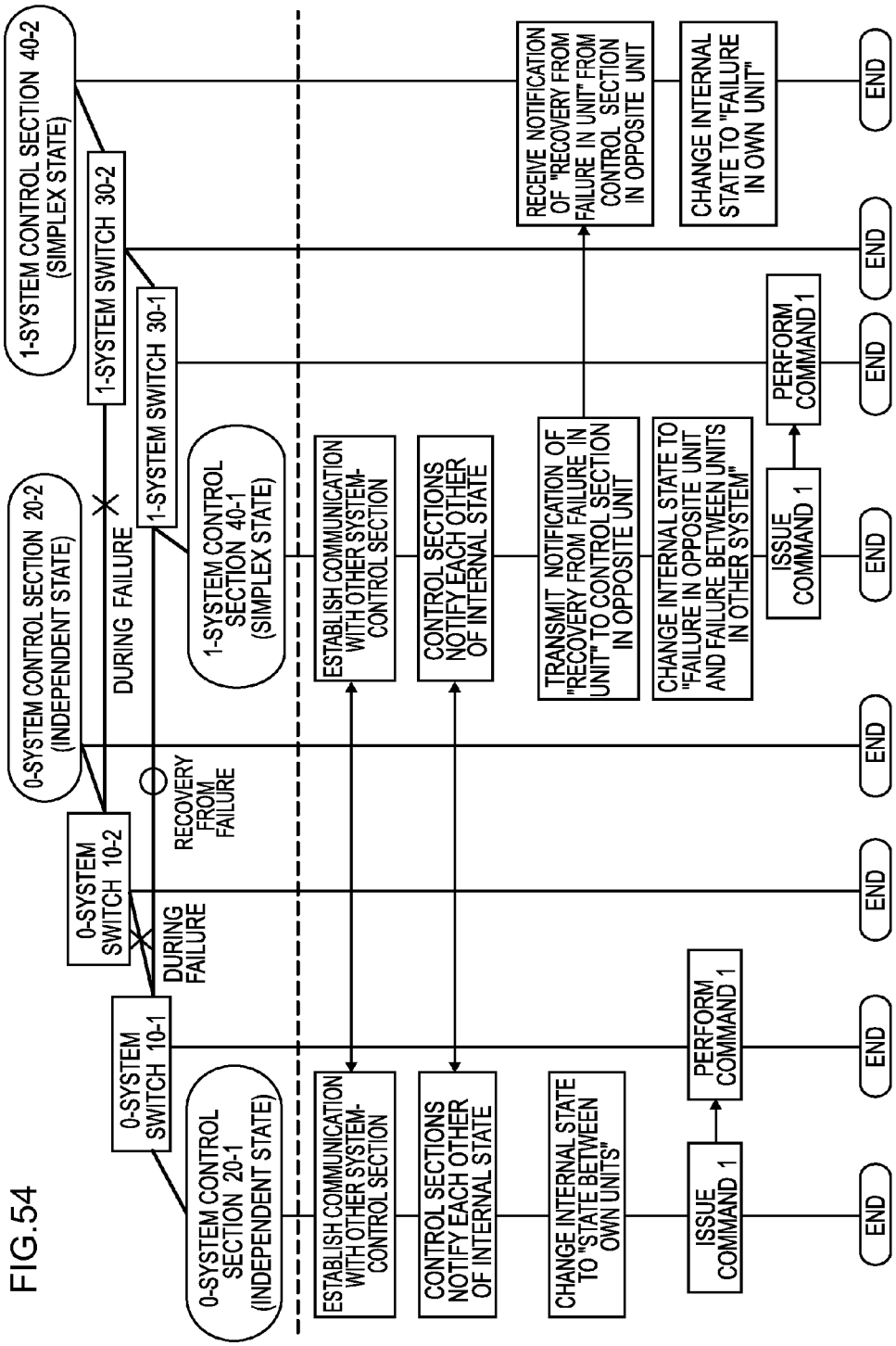

0-SYSTEM CONTROL SECTION 20-2 (INDEPENDENT STATE)
1-SYSTEM CONTROL SECTION 40-2 (FAILURE BETWEEN UNITS IN OWN SYSTEM)
0-SYSTEM SWITCH 10-2
0-SYSTEM SWITCH 10-1
1-SYSTEM SWITCH 30-2
1-SYSTEM SWITCH 30-1
DURING FAILURE
DURING FAILURE
FAILURE OCCURS
0-SYSTEM CONTROL SECTION 20-1 (FAILURE BETWEEN OPPOSITE UNITS)
1-SYSTEM CONTROL SECTION 40-1 (FAILURE IN OPPOSITE UNIT AND FAILURE BETWEEN UNITS IN OTHER SYSTEM)
IT IS DETECTED THAT COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION IS UNAVAILABLE
IT IS DETECTED THAT COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION IS UNAVAILABLE
ISSUE COMMAND 3
ISSUE COMMAND 3
PERFORM COMMAND 3
PERFORM COMMAND 3
TRANSMIT NOTIFICATION OF "FAILURE IN UNIT" TO CONTROL SECTION IN OPPOSITE UNIT
RECEIVE NOTIFICATION OF "FAILURE IN UNIT" FROM CONTROL SECTION IN OPPOSITE UNIT
CHANGE INTERNAL STATE TO "INDEPENDENT STATE"
CHANGE INTERNAL STATE TO "SIMPLEX STATE"
CHANGE INTERNAL STATE TO "SIMPLEX STATE"
END
END
END
END
END
END
END

FIG.53

FIG.54


0-SYSTEM CONTROL SECTION 20-1 (INDEPENDENT STATE)
0-SYSTEM CONTROL SECTION 20-2 (INDEPENDENT STATE)
1-SYSTEM CONTROL SECTION 40-1 (SIMPLEX STATE)
1-SYSTEM CONTROL SECTION 40-2 (SIMPLEX STATE)
0-SYSTEM SWITCH 10-1
0-SYSTEM SWITCH 10-2
1-SYSTEM SWITCH 30-1
1-SYSTEM SWITCH 30-2
DURING FAILURE
RECOVERY FROM FAILURE
ESTABLISH COMMUNICATION WITH OTHER SYSTEM-CONTROL SECTION
CONTROL SECTIONS NOTIFY EACH OTHER OF INTERNAL STATE
CHANGE INTERNAL STATE TO "STATE BETWEEN OWN UNITS"
ISSUE COMMAND 1
PERFORM COMMAND 1
TRANSMIT NOTIFICATION OF "RECOVERY FROM FAILURE IN UNIT" TO CONTROL SECTION IN OPPOSITE UNIT
CHANGE INTERNAL STATE TO "FAILURE IN OPPOSITE UNIT AND FAILURE BETWEEN UNITS IN OTHER SYSTEM"
RECEIVE NOTIFICATION OF "RECOVERY FROM FAILURE IN UNIT" FROM CONTROL SECTION IN OPPOSITE UNIT
CHANGE INTERNAL STATE TO "FAILURE IN OWN UNIT"
END

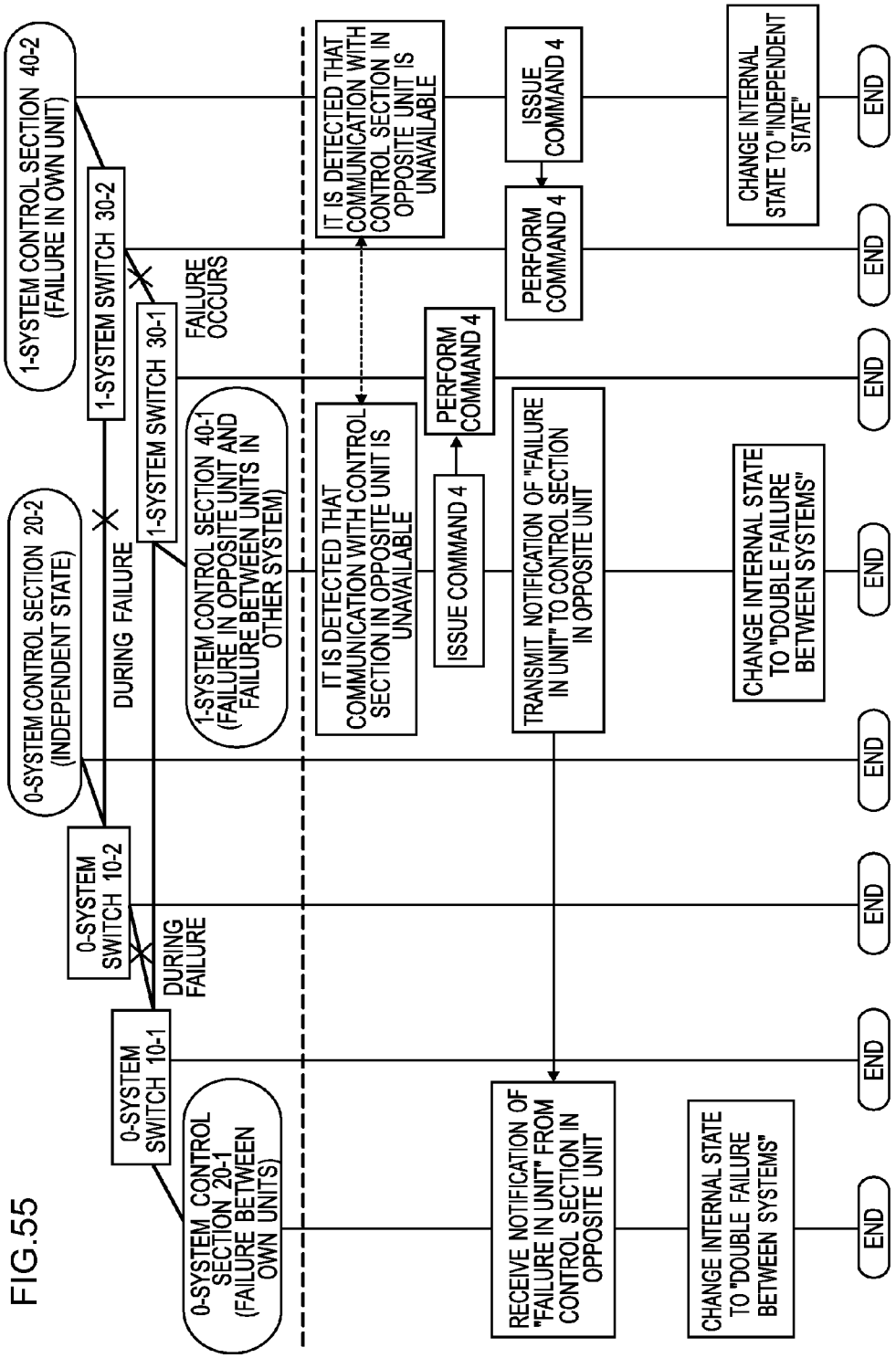

0-SYSTEM CONTROL SECTION 20-1 (FAILURE BETWEEN OWN UNITS)
0-SYSTEM SWITCH 10-1
0-SYSTEM SWITCH 10-2
0-SYSTEM CONTROL SECTION 20-2 (INDEPENDENT STATE)
1-SYSTEM CONTROL SECTION 40-2 (FAILURE IN OWN UNIT)
DURING FAILURE
1-SYSTEM SWITCH 30-1
1-SYSTEM SWITCH 30-2
FAILURE OCCURS
1-SYSTEM CONTROL SECTION 40-1 (FAILURE IN OPPOSITE UNIT AND FAILURE BETWEEN UNITS IN OTHER SYSTEM)
IT IS DETECTED THAT COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT IS UNAVAILABLE
IT IS DETECTED THAT COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT IS UNAVAILABLE
ISSUE COMMAND 4
PERFORM COMMAND 4
TRANSMIT NOTIFICATION OF "FAILURE IN UNIT" TO CONTROL SECTION IN OPPOSITE UNIT
ISSUE COMMAND 4
PERFORM COMMAND 4
RECEIVE NOTIFICATION OF "FAILURE IN UNIT" FROM CONTROL SECTION IN OPPOSITE UNIT
CHANGE INTERNAL STATE TO "DOUBLE FAILURE BETWEEN SYSTEMS"
CHANGE INTERNAL STATE TO "DOUBLE FAILURE BETWEEN SYSTEMS"
CHANGE INTERNAL STATE TO "INDEPENDENT STATE"
END
END
END
END
END
END
END
END

FIG.55

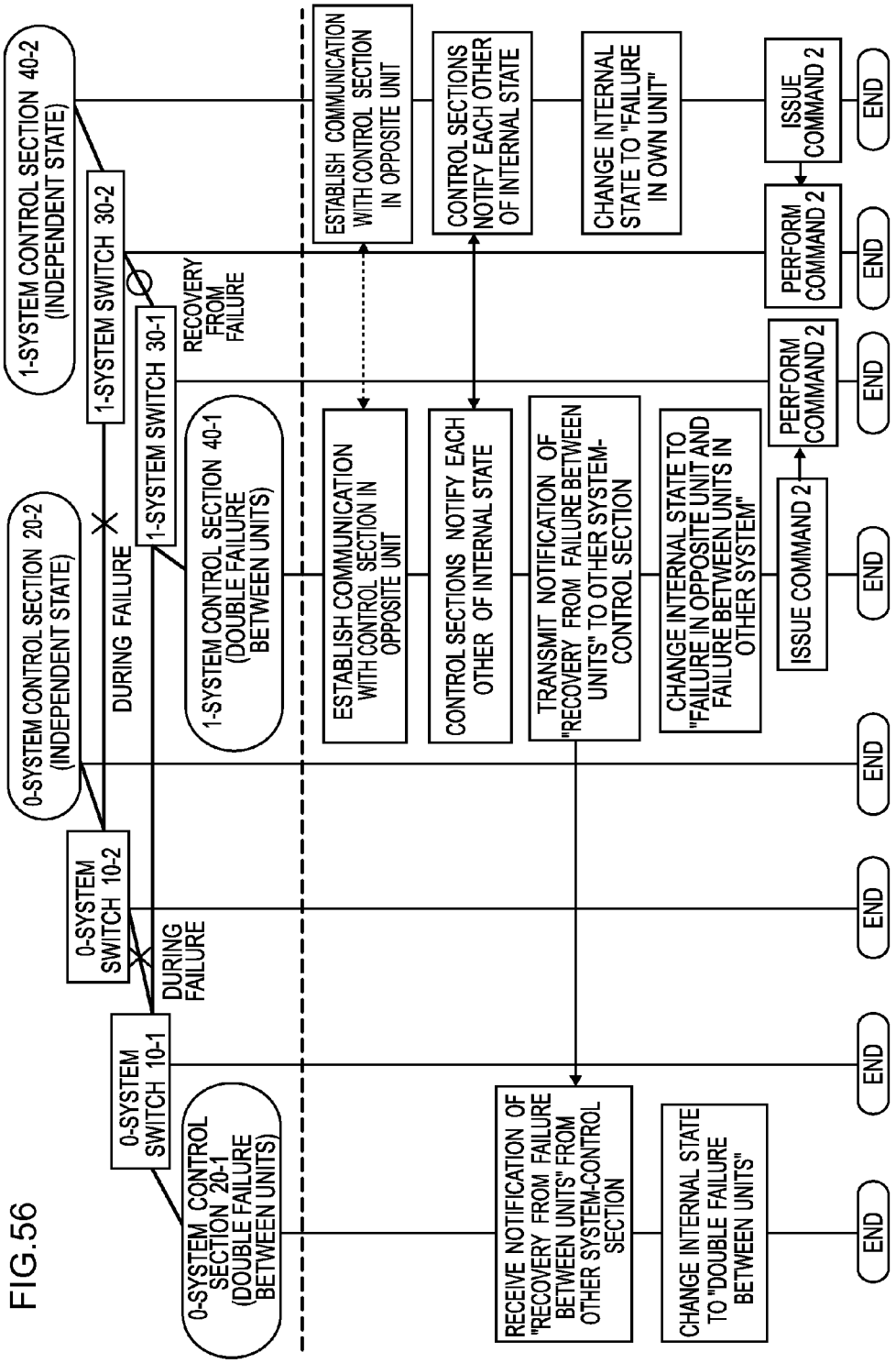

0-SYSTEM CONTROL SECTION 20-2 (INDEPENDENT STATE)
0-SYSTEM SWITCH 10-2
0-SYSTEM SWITCH 10-1
0-SYSTEM CONTROL SECTION 20-1 (DOUBLE FAILURE BETWEEN UNITS)
DURING FAILURE
DURING FAILURE
1-SYSTEM CONTROL SECTION 40-2 (INDEPENDENT STATE)
1-SYSTEM SWITCH 30-2
1-SYSTEM SWITCH 30-1
RECOVERY FROM FAILURE
1-SYSTEM CONTROL SECTION 40-1 (DOUBLE FAILURE BETWEEN UNITS)
ESTABLISH COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT
CONTROL SECTIONS NOTIFY EACH OTHER OF INTERNAL STATE
TRANSMIT NOTIFICATION OF "RECOVERY FROM FAILURE BETWEEN UNITS" TO OTHER SYSTEM-CONTROL SECTION
CHANGE INTERNAL STATE TO "FAILURE IN OPPOSITE UNIT AND FAILURE BETWEEN UNITS IN OTHER SYSTEM"
ISSUE COMMAND 2
PERFORM COMMAND 2
ESTABLISH COMMUNICATION WITH CONTROL SECTION IN OPPOSITE UNIT
CONTROL SECTIONS NOTIFY EACH OTHER OF INTERNAL STATE
CHANGE INTERNAL STATE TO "FAILURE IN OWN UNIT"
ISSUE COMMAND 2
PERFORM COMMAND 2
RECEIVE NOTIFICATION OF "RECOVERY FROM FAILURE BETWEEN UNITS" FROM OTHER SYSTEM-CONTROL SECTION
CHANGE INTERNAL STATE TO "DOUBLE FAILURE BETWEEN UNITS"
END
END
END
END
END
END
END
END
END

FIG.56

FIG.57

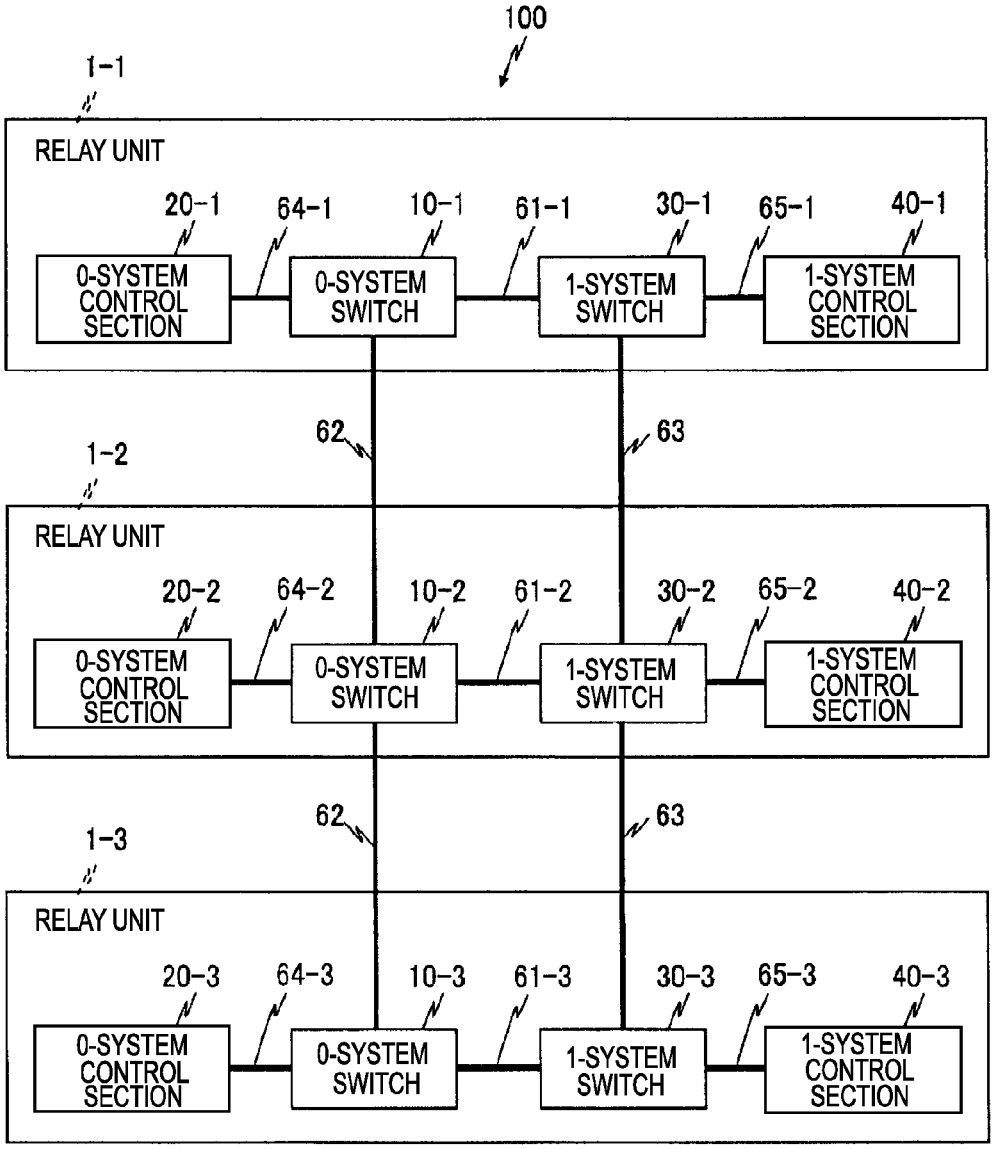

100
1-1
RELAY UNIT
20-1
64-1
10-1
61-1
30-1
65-1
40-1
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
62
63
1-2
RELAY UNIT
20-2
64-2
10-2
61-2
30-2
65-2
40-2
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
62
63
1-3
RELAY UNIT
20-3
64-3
10-3
61-3
30-3
65-3
40-3
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION

FIG.58

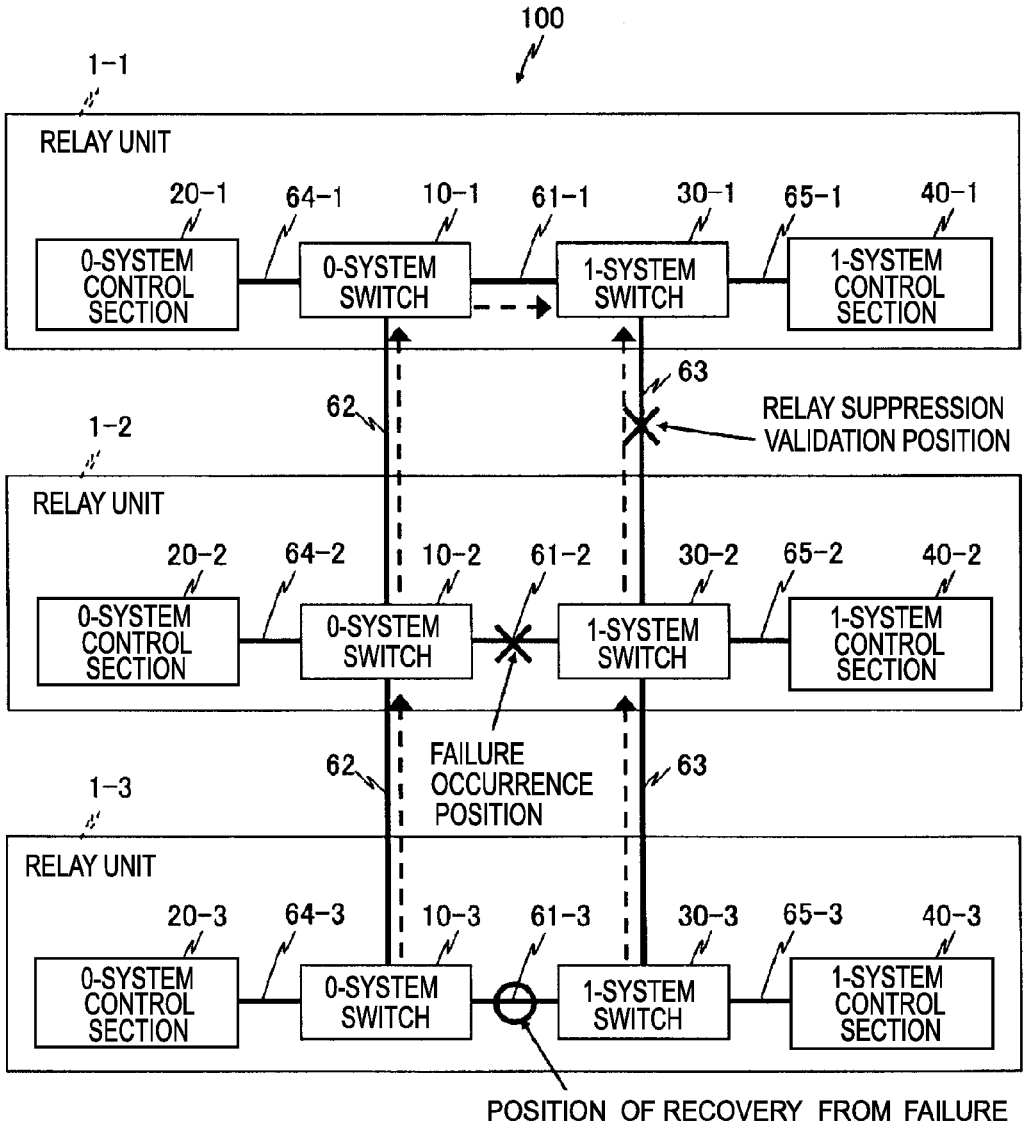

100
1-1
RELAY UNIT
20-1
64-1
10-1
61-1
30-1
65-1
40-1
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
62
63
RELAY SUPPRESSION VALIDATION POSITION
1-2
RELAY UNIT
20-2
64-2
10-2
61-2
30-2
65-2
40-2
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
FAILURE OCCURRENCE POSITION
62
63
1-3
RELAY UNIT
20-3
64-3
10-3
61-3
30-3
65-3
40-3
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
POSITION OF RECOVERY FROM FAILURE

FIG.59

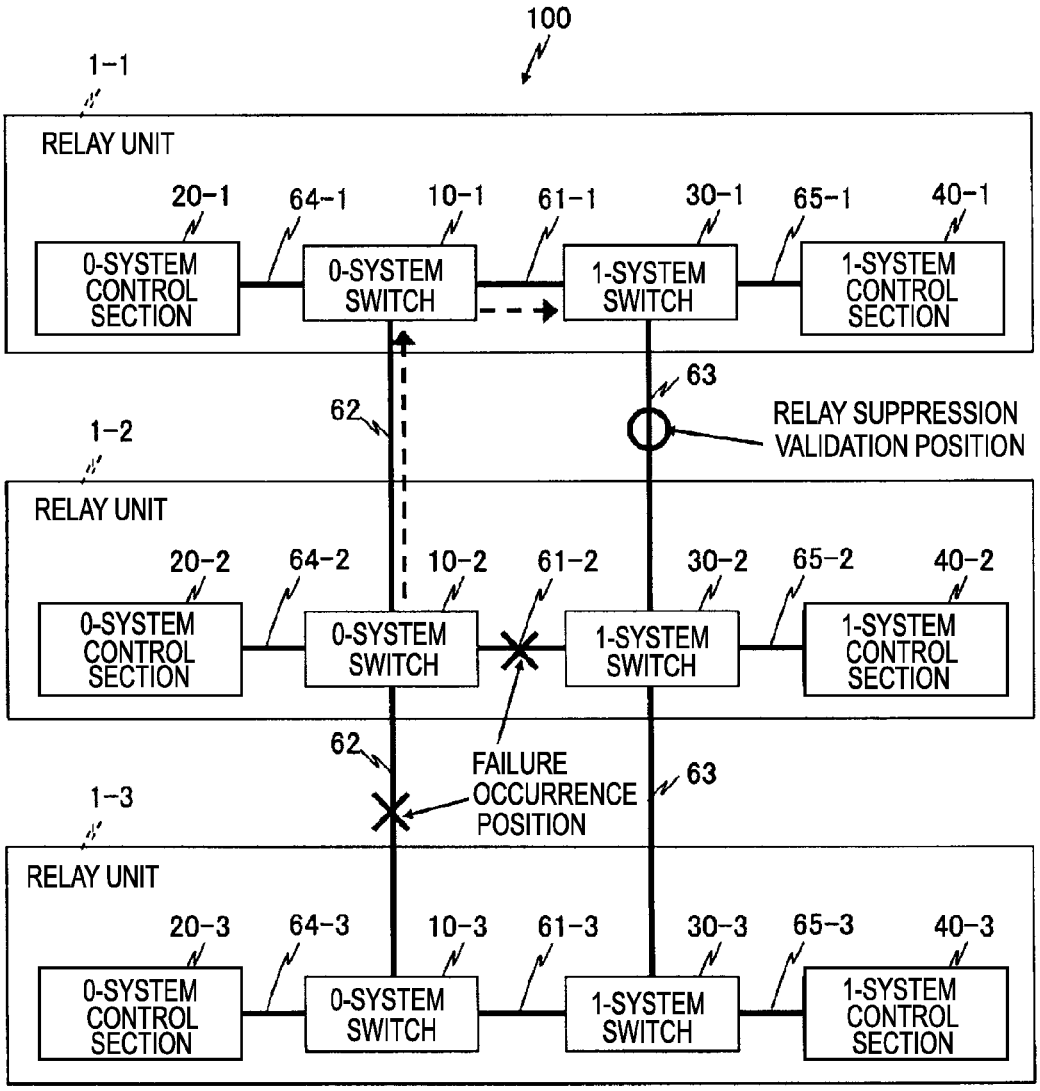

100
1-1
RELAY UNIT
20-1
64-1
10-1
61-1
30-1
65-1
40-1
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
62
63
RELAY SUPPRESSION VALIDATION POSITION
1-2
RELAY UNIT
20-2
64-2
10-2
61-2
30-2
65-2
40-2
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
62
FAILURE OCCURRENCE POSITION
63
1-3
RELAY UNIT
20-3
64-3
10-3
61-3
30-3
65-3
40-3
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION

FIG.60

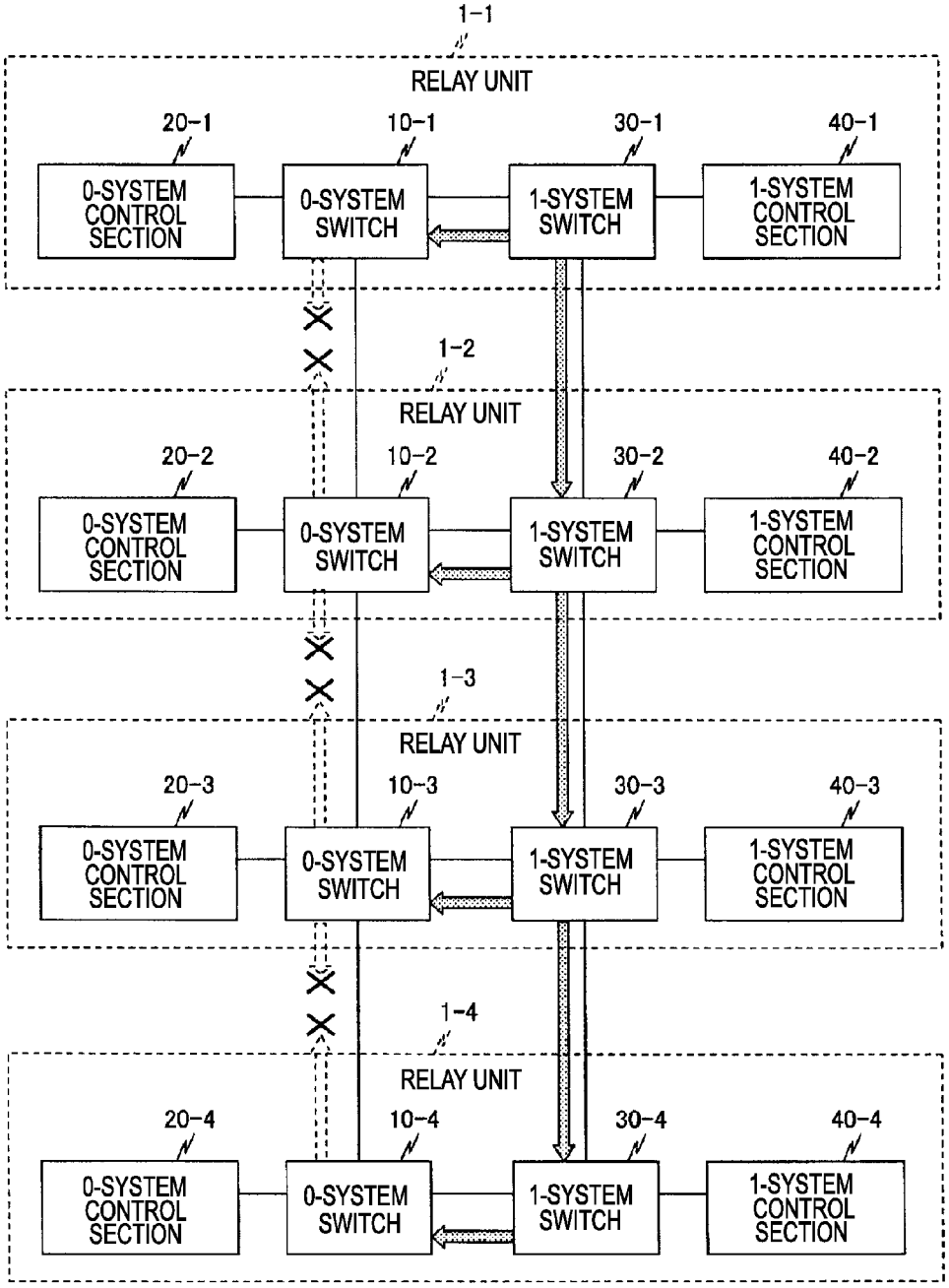
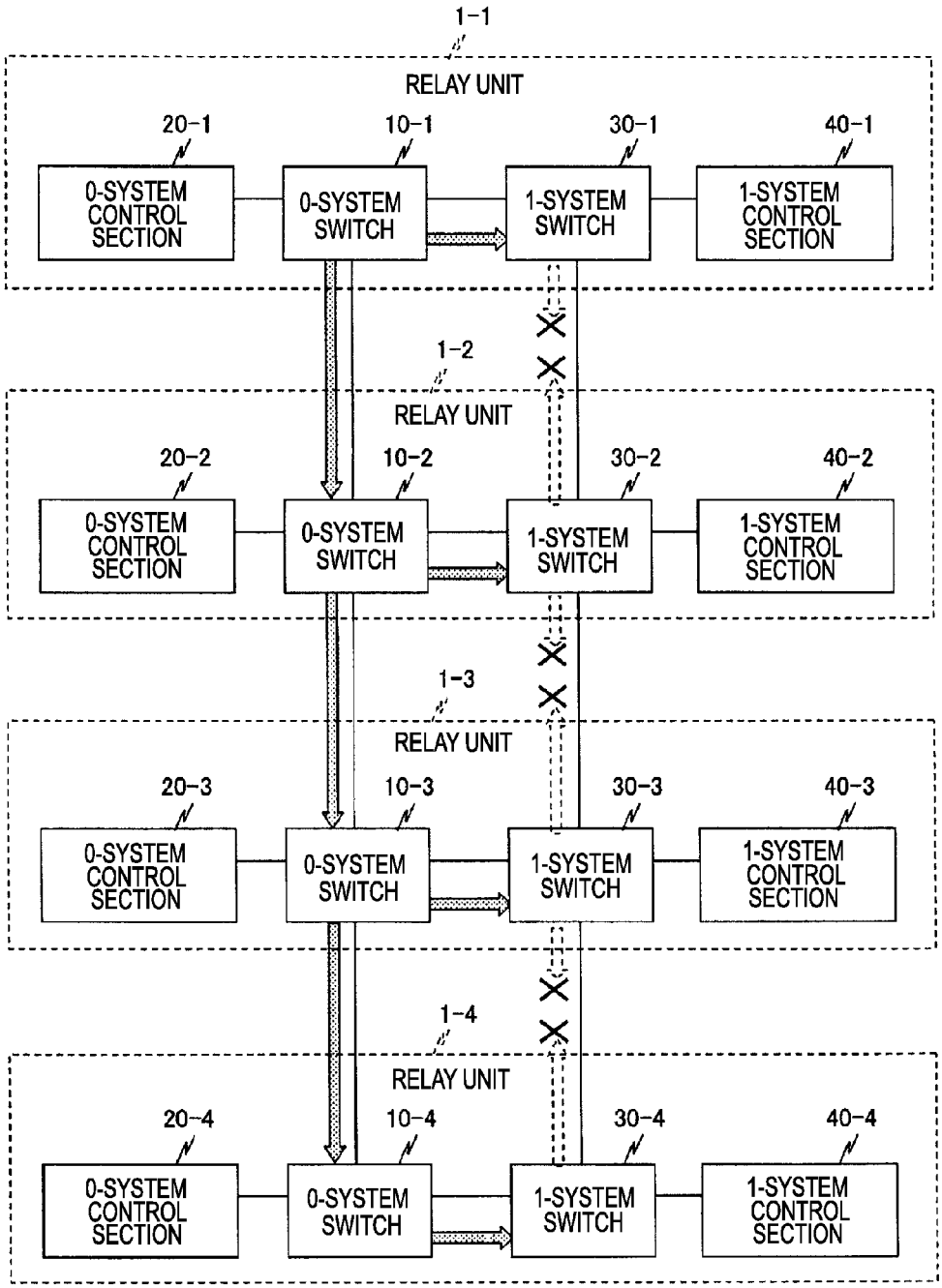

1-1
RELAY UNIT
20-1
10-1
30-1
40-1
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
1-2
RELAY UNIT
20-2
10-2
30-2
40-2
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
1-3
RELAY UNIT
20-3
10-3
30-3
40-3
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
1-4
RELAY UNIT
20-4
10-4
30-4
40-4
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION

FIG.61


1-1
RELAY UNIT
20-1
10-1
30-1
40-1
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
1-2
RELAY UNIT
20-2
10-2
30-2
40-2
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
1-3
RELAY UNIT
20-3
10-3
30-3
40-3
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION
1-4
RELAY UNIT
20-4
10-4
30-4
40-4
0-SYSTEM CONTROL SECTION
0-SYSTEM SWITCH
1-SYSTEM SWITCH
1-SYSTEM CONTROL SECTION

RELAY UNIT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority under 35 USC 119 from Japanese Patent Application No. 2011-216493 filed on Sep. 30, 2011, the disclosure of which is incorporated by reference herein.

BACKGROUND OF THE INVENTION

1. Technical of the Field

The invention relates to a relay unit which include two-system switches that relay frames and which is cascaded in multiple stages to form a LAN.

2. Description of the Related Art

For example, in a communication network such as a layer 2 network, a structure has been used in which plural switches are connected to each other in a ring shape or a mesh shape in order to achieve redundancy with respect to the relay of frames. When this structure is simply used as is, frames are continuously looped between the switches. As a technique for preventing an infinite loop of frames, a spanning tree technique is known, for example. This technique determines a root switch based on an ID exchanged among the switches and determines a port to be invalidated based on a path cost from the root switch, thereby forming a loop-free tree structure. In addition, for example, Japanese Patent Application Laid-Open (JP-A) No. 2007-174119 discloses a technique for preventing a loop. JP-A No. 2007-174119 discloses a technique that arranges switches in a ring shape, and blocks the relay of frames using a specific port when a master device, which is one of the switches, has detected a loop, thereby preventing looping of frames.

However, in the spanning tree structure, since one switch is a root switch, the position at which the relay of frames is blocked is fixed and it is difficult to flexibly switch the relay routes when a failure occurs. As a result, it is difficult to effectively use the relay paths that can be formed between the switches. In addition, in JP-A No. 2007-174119, a loop is detected using the master device as the base, and the master device blocks the relay of frames using a specific port. Therefore, a similar situation occurs. In these techniques, when relay units including the switches are cascaded in multiple stages, it is thought that it is difficult to flexibly change the switching aspect of the relay route according to the number of connections.

SUMMARY OF THE INVENTION

The present invention has been made in view of the above circumstances and provides a relay unit.

According to a first aspect of the invention, there is provided a relay unit, the relay unit being configured to cascade in multiple stages to form a LAN and including: a main-system line and a sub-system line that relay a frame; an inter-system line that connects the main-system line and the sub-system line; a main-system switch and a sub-system switch that are connected to each other via the inter-system line, that are connected to the main-system line and the sub-system line, respectively, and that relay frames; and control sections that control a relay operation of each of the main-system switch and the sub-system switch, that can store information on a number of connections of relay units in the LAN and information on a connection priority of the relay unit to which the control sections belong, and that select a control aspect of the relay operation of at least one of the main-system switch and the sub-system switch according to the number of connections and the connection priority.

According to the relay unit of the first aspect of the invention, it is possible to form a network such that the number of connections can be flexibly increased or decreased and it is possible to effectively use the relay paths that can be formed among the switches.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will be described in detail based on the following figures, wherein:

FIG. **1** is a block diagram illustrating the structure of a relay system according to a first embodiment of the invention;

FIG. **2** is a block diagram illustrating the structure of the 0-system switch in FIG. **1**;

FIG. **3** is a diagram illustrating an example of the path information table in FIG. **2**;

FIG. **4** is a block diagram illustrating the structure of the 1-system switch in FIG. **1**;

FIG. **5** is a block diagram illustrating the structure of the 0-system control section in FIG. **1**;

FIG. **6** is a block diagram illustrating the structure of the 1-system control section in FIG. **1**;

FIG. **7** is a diagram illustrating a connection state which may be stored in the connection state storage section in FIGS. **5** and **6**;

FIG. **8** is a diagram illustrating, with arrows, a communication state when the connection state in FIG. **7** is "perfect state";

FIG. **9** is a diagram illustrating, with arrows, a communication state when the connection state in FIG. **7** is "failure between units in the other system" and "failure between units in the own system";

FIG. **10** is a diagram illustrating, with arrows, a communication state when the connection state in FIG. **7** is "failure in the own unit" and "failure in the opposite unit";

FIG. **11** is a diagram illustrating, with arrows, a connection state when the connection state in FIG. **7** is "double failure between units";

FIG. **12** is a diagram illustrating, with arrows, a communication state when the connection state in FIG. **7** is "simplex state";

FIG. **13** is a diagram illustrating, with arrows, a communication state when the connection state in FIG. **7** includes a state of "failure between units in the other system and failure in the opposite unit";

FIG. **14** is a diagram illustrating a list of information items communicated between the control sections in FIG. **1**;

FIG. **15** is a diagram illustrating a list of commands which may be issued from each of the control sections in FIG. **1** to a control target switch;

FIG. **16** is a flowchart illustrating the processing routine for establishing initial communication with the other system-control section;

FIG. **17** is a sequence diagram illustrating the operations of switches and control sections in two systems at the time of the processing for establishing initial communication with the other system-control section;

FIG. **18** is a diagram illustrating a transition table of connection states at the time of the processing for establishing initial communication with the other system-control section;

FIG. **19** is a flowchart illustrating a relay control application determining processing routine;

FIG. **20** is a flowchart illustrating the processing routine for establishing initial communication with the opposing control section;

FIG. **21** is a sequence diagram illustrating the operations of the switches and the control sections in two systems at the time of the processing for establishing initial communication with the opposing control section;

FIG. **22** is a flowchart illustrating a processing routine when an inter-unit communication establishment notification is received;

FIG. **23** is a diagram illustrating a transition table of connection states when an inter-unit communication establishment notification is received;

FIG. **24** is a diagram illustrating a transition table of connection states at the time of the processing for establishing initial communication with the opposing control section;

FIG. **25** is a diagram illustrating a frame relay flow from the 1-system switch when the relay of a specific frame is suppressed;

FIG. **26** is a diagram illustrating a frame relay flow from the 0-system switch when the relay of a specific frame is suppressed;

FIG. **27** is a flowchart illustrating a processing routine when failure between units is detected;

FIG. **28** is a diagram illustrating a transition table of connection states when failure between units is detected;

FIG. **29** is a flowchart illustrating a processing routine when failure in the own unit is detected;

FIG. **30** is a diagram illustrating a transition table of connection states when failure in the own unit is detected;

FIG. **31** is a flowchart illustrating a processing routine when an inter-unit failure occurrence notification is received;

FIG. **32** is a diagram illustrating a transition table of connection states when the inter-unit failure occurrence notification is received;

FIG. **33** is a flowchart illustrating a processing routine when notification of the occurrence of failure in a unit is received;

FIG. **34** is a diagram illustrating a transition table of connection states when notification of the occurrence of failure in a unit is received;

FIG. **35** is a flowchart illustrating a processing routine when notification of the establishment of communication in a unit is received;

FIG. **36** is a diagram illustrating a transition table of connection states when notification of the establishment of communication in a unit is received;

FIG. **37** is a diagram illustrating an operation flow when failure occurs in a unit in a state in which there is no failure;

FIG. **38** is a diagram illustrating an operation flow when inter-unit failure occurs in a state in which there is no failure;

FIG. **39** is a diagram illustrating an operation flow when failure in a unit is remedied;

FIG. **40** is a diagram illustrating an operation flow when inter-unit failure is remedied;

FIG. **41** is a diagram illustrating an operation flow when failure occurs between units of both of two systems;

FIG. **42** is a diagram illustrating an operation flow when failure in one system is remedied from a state in which failure occurs between units of both of two systems;

FIG. **43** is a diagram illustrating an operation flow when failure occurs in two units;

FIG. **44** is a diagram illustrating an operation flow when failure in one unit is remedied from a state in which failure occurs in both of two units;

FIG. **45** is a diagram illustrating an operation flow when inter-unit failure occurs in a state in which failure occurs in one of two units;

FIG. **46** is a diagram illustrating an operation flow when inter-unit failure is remedied in a state in which both failure occurs in a unit and inter-unit failure occurs;

FIG. **47** is a diagram illustrating an operation flow when failure occurs in a unit in a state in which inter-unit failure occurs;

FIG. **48** is a diagram illustrating an operation flow when failure in a unit is remedied from a state in which both failure occurs in the unit and inter-unit failure occurs;

FIG. **49** is a diagram illustrating an operation flow when failure occurs in a unit in a state in which double failure occurs between the units in both of two systems;

FIG. **50** is a diagram illustrating an operation flow when failure in a unit which is in an independent state is remedied in both of two systems;

FIG. **51** is a diagram illustrating an operation flow when failure occurs between two units, both of which are in a simplex state;

FIG. **52** is a diagram illustrating an operation flow when failure between two units which are both in an independent state is remedied;

FIG. **53** is a diagram illustrating an operation flow when failure occurs in another unit in a state in which both failure occurs in one unit and failure occurs between opposing units;

FIG. **54** is a diagram illustrating an operation flow when failure in one unit is remedied in a state in which failure occurs in both of two units and failure occurs between units in one system;

FIG. **55** is a diagram illustrating an operation flow when failure occurs between units in the other system in a state in which failure occurs in one unit and failure occurs between units in one system;

FIG. **56** is a diagram illustrating an operation flow when failure between units in one system is remedied in a state in which failure occurs in one unit and failure occurs between units in both of two systems;

FIG. **57** is a block diagram illustrating the structure of a relay system according to a second embodiment of the invention;

FIG. **58** is a diagram illustrating a position of recovery from failure, a failure occurrence position, a relay suppression validation position, and the flow of an inter-system communication validation notification in the relay system in FIG. **57**;

FIG. **59** is a diagram illustrating a failure occurrence position, a relay suppression invalidation position, and the flow of an inter-system communication invalidation notification in the relay system in FIG. **57**;

FIG. **60** is a diagram illustrating a frame relay flow from a 1-system switch when relay units are connected in four stages and the relay of a specific frame is suppressed; and

FIG. **61** is a diagram illustrating a frame relay flow from a 0-system switch when relay units are connected in four stages and the relay of a specific frame is suppressed.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, exemplary embodiments of the invention will be described in detail with reference to the accompanying drawings.

<First Embodiment>

FIG. **1** illustrates the structure of a relay system **100** according to an embodiment of the invention. The relay system **100** includes host terminals **51-1** to **51**-n (n is an integer equal to or greater than 2) and relay units **1-1** and **1-2** which

relay frames between host terminals **52-1** to **52**-m (m is an integer equal to or greater than 2). The relay unit **1-1** and the relay unit **1-2** are cascaded via relay paths **62** and **63** to form a local area network (LAN).

The relay unit **1-1** includes a 0-system switch **10-1** and a 1-system switch **30-1** which are duplicated for the redundancy of a frame relay path, a 0-system control section **20-1** which controls the 0-system switch **10-1**, and a 1-system control section **40-1** which controls the 1-system switch **30-1**. Similarly, the relay unit **1-2** includes a 0-system switch **10-2** and a 1-system switch **30-2** which are duplicated for the redundancy of a frame relay path, a 0-system control section **20-2** which controls the 0-system switch **10-2**, and a 1-system control section **40-2** which controls the 1-system switch **30-2**. Hereinafter, the 0-system switches **10-1** and **10-2** are also referred to as main-system switches and the 1-system switches **30-1** and **30-2** are also referred to as sub-system switches.

Each of the host terminals **51-1** to **51**-n can transmit and receive frames to and from one of the 0-system switch **10-1** and the 1-system switch **30-1** which is selected as a currently used system. Similarly, each of the host terminals **52-1** to **52**-m can transmit and receive frames to and from one of the 0-system switch **10-2** and the 1-system switch **30-2** which is selected as a currently used system. These host terminals are, for example, terminals with a communication function, such as personal computers.

The 0-system switch **10-1** and the 1-system switch **30-1** can relay frames each other via a relay path **61-1** in the relay unit **1-1**. Similarly, the 0-system switch **10-2** and the 1-system switch **30-2** can relay frames each other via a relay path **61-2** in the relay unit **1-2**. In addition, the 0-system switch **10-1** and the 0-system switch **10-2** can relay frames each other between the units via the relay path **62**. Similarly, the 1-system switch **30-1** and the 1-system switch **30-2** can relay frames each other between the units via the relay path **63**. These switches are, for example, layer 2 switches (L2SW). Hereinafter, the relay path **62** and the relay path **63** are referred to as a main-system line and a sub-system line, respectively. Each of the relay paths **61-1** and **61-2** is referred to as an inter-system line.

The 0-system control section **20-1** can issue various commands to the 0-system switch **10-1** via a communication path **64-1** to control the 0-system switch **10-1**. The 1-system control section **40-1** can issue various commands to the 1-system switch **30-1** via a communication path **65-1** to control the 1-system switch **30-1**. Similarly, the 0-system control section **20-2** can issue various commands to the 0-system switch **10-2** via a communication path **64-2** to control the 0-system switch **10-2**. The 1-system control section **40-2** can issue various commands to the 1-system switch **30-2** via a communication path **65-2** to control the 1-system switch **30-2**.

The 0-system control section **20-1** and the 1-system control section **40-1** can establish communication in units each other via the communication path **64-1**, the relay path **61-1**, and the communication path **65-1**. Similarly, the 0-system control section **20-2** and the 1-system control section **40-2** can establish communication in units each other via the communication path **64-2**, the relay path **61-2**, and the communication path **65-2**. The 0-system control section **20-1** and the 0-system control section **20-2** can establish inter-unit communication each other via the communication path **64-1**, the relay path **62**, and the communication path **64-2**. Similarly, the 1-system control section **40-1** and the 1-system control section **40-2** can establish inter-communication each other via the communication path **65-1**, the relay path **63**, and the communication path **65-2**. Each of the control sections is, for example, a CPU that executes a predetermined communication control program.

FIG. **2** illustrates the structure of the 0-system switch **10-1**. A relay unit **11** relays various frames among the 0-system control section **20-1** in the relay unit **1-1**, which is an own unit (a self unit), the 1-system switch **30-1** in the own unit, and the 0-system switch **10-2** in the relay unit **1-2**, which is the next-order relay unit. In this embodiment, only two relay units, that is, the relay units **1-1** and **1-2**, are provided. Therefore, when the relay unit **1-1** is a main unit, the relay unit **1-2** is referred to as an opposite unit (an opposing unit).

If the transmission source address of the transmitted frame is stored in a path information table **12**, the relay section **11** transmits the frame to a relay path corresponding to the transmission source address. If the transmission source address is not stored in the path information table **12**, the relay section **11** relays the frame to all of the relay paths corresponding to VLAN to which the frame belongs. The relay section **11** starts, stops, suppresses, and resumes the relay of frames for specific traffic in response to a relay permission command, a relay prohibition command, a relay suppression validation command, and a relay suppression invalidation command from the 0-system control section **20-1**. These commands are notified by the frames via the communication path **64-1**.

FIG. **3** illustrates an example of the path information table **12**. An "address" is the MAC address of a relay destination. A "virtual group" is a virtual network group, that is, a VLAN group. The groups include, for example, a group (hereinafter, referred to as VLAN_A) for relaying a user frame, a group (hereinafter, referred to as VLAN_B) for relaying a control frame between the control sections in the same unit, and a group (hereinafter, referred to as VLAN_C) for relaying a control frame between the control sections in the opposite unit.

The relay paths **61-1** and **61-2** in the same unit belong to both VLAN_A and VLAN_B as trunk lines, and traffics are virtually separated into VLAN_A and VLAN_B such that the frames of the VLAN_A and VLAN_B do not intersect each other.

The relay paths **62** and **63** between the opposite units belong to both VLAN_A and VLAN_C as trunk lines, and traffics are virtually separated into VLAN_A and VLAN_C such that the frames of the VLAN_A and VLAN_C do not intersect each other.

The communication paths **64-1**, **64-2**, **65-1**, and **65-2** among the switches and the control sections belong to both VLAN_B and VLAN_C as trunk lines, and traffics are virtually separated into VLAN_B and VLAN_C such that the frames of the VLAN_B and VLAN_C do not intersect each other.

The "transmission path" indicates the relay destination of frames. In FIG. **3**, the relay path **61-1** and the relay path **62** are illustrated as an example. The transmission paths are in one-to-one correspondence with ports. The relay section **11** transmits the received frame to the transmission path corresponding to the transmission source MAC address of the frame.

When the transmission source MAC address which is included in the frame transmitted to the relay section **11** is not stored in the path information table **12**, the path information update section **13** associates the transmission source MAC address with the transmission path and stores them in the path information table **12**. The path information update section **13** deletes the MAC address in the path information table **12** in response to a MAC address deletion command from the 0-system control section **20-1**.

A failure detecting section **14** monitors the frames relayed by the relay section **11** and the state of the communication path connected to the relay section **11** to detect a traffic failure. For example, the failure can be detected by a keep-alive function of a switch manufactured by Cisco Systems, Inc. When a failure is detected, the failure detecting section **14** transmits a failure detection notification to the 0-system control section **20-1**. At that time, the failure detecting section **14** also notifies the 0-system control section **20-1** of a relay path (for example, the relay path **61-1** or **62**) where a failure has occurred.

The 0-system switch **10-2** has the same structure as that of the 0-system switch **10-1**.

FIG. **4** illustrates the structure of the 1-system switch **30-1**.

A relay section **31** relays various frames among the 1-system control section **40-1** in the relay unit **1-1**, which is an own unit, the 0-system switch **10-1** in the own unit, and the 1-system switch **30-2** in the relay unit **1-2**, which is the next order (opposite) unit. If the transmission source address of the received frame is stored in a path information table **32**, the relay section **31** transmits the frame to a relay path corresponding to the transmission source address. If the transmission source address is not stored in the path information table **32**, the relay section **31** relays the frame to all of the relay paths corresponding to VLAN to which the frame belongs. The relay section **31** starts, stops, suppresses, and resumes the relay of frames for specific traffic in response to a relay permission command, a relay prohibition command, a relay suppression validation command, and a relay suppression invalidation command from the 1-system control section **40-1**. These commands are notified by the frames via the communication path **65-1**. The path information table **32** is the same as that illustrated in FIG. **3**.

If the transmission source MAC address, which is included in the frame transmitted to the relay section **31**, is not stored in the path information table **32**, a path information update section **33** associates the transmission source MAC address with the transmission path to store them in the path information table **32**. The path information update section **33** deletes the MAC address in the path information table **32** in response to one MAC address deletion command from the 1-system control section **40-1**.

The failure detecting section **34** monitors packets relayed by the relay section **31** and the state of the communication path connected to the relay section **31** to detect a traffic failure. The failure can be detected by a keep-alive function of a switch manufactured by Cisco Systems, Inc. If a failure is detected, the failure detecting section **34** transmits a failure detection notification to the 1-system control section **40-1**. At that time, the failure detecting section **34** also notifies the 1-system control section **40-1** of a relay path (for example, the relay path **61-1** or **63**) where a failure has occurred.

The 1-system switch **30-2** has the same structure as the 1-system switch **30-1**.

FIG. **5** illustrates the structure of the 0-system control section **20-1**. The 0-system control section **20-1** controls the 0-system switch **10-1** as a control target switch.

A connection state storage section **21** stores data indicating the connection state among the switches and the control sections. The connection state can be updated by a state update section **23**. The connection state will be described in detail below (see FIG. **7**). The connection state storage section **21** may also store the number of connections (N) between the relay units **1-1** and **1-2** and the connection priority (P) of the relay unit **1-1**, which is an own unit. In this embodiment, the number of connections is "2". The connection priority of the relay unit **1-1** is, for example, "1", and the connection priority of the relay unit **1-2** is, for example, "2". The connection state storage section **21** is a storage device, such as a RAM or a hard disk. The number of connections and the connection priority are stored in the storage device and they can be rewritten.

The notification receiving section **22** receives the failure detection notification from the 0-system switch **10-1**, and receives a connection state notification, a communication establishment notification, and a failure occurrence notification from the 1-system control section **40-1** in the own unit or the 0-system control section **20-2** in the opposite unit.

The state update section **23** updates the connection state of the connection state storage section **21** according to the content of the notifications. The content of the update will be described in detail below (see FIG. **18**, FIG. **22**, FIG. **26**, FIG. **28**, FIG. **30**, FIG. **32**, FIG. **34**, and FIG. **36**).

A connection state notifying section **24** notifies the 1-system control section **40-1** in the own unit and/or the 0-system control section **20-2** in the opposite unit, of the connection state stored in the connection state storage section **21**. In addition, the connection state notifying section **24** transmits the communication establishment notification and the failure occurrence notification to the 1-system control section **40-1** and/or the 0-system control section **20-2**.

A command section **25** transmits various commands to the 0-system switch **10-1**, which is a control target switch, based on the connection state stored in the connection state storage section **21**, thereby controlling the 0-system switch **10-1**. The commands will be described in detail below (FIG. **14**).

A communication establishment section **26** establishes communication between the 1-system control section **40-1** and the 0-system control section **20-2**.

The notification receiving section **22**, the state update section **23**, the connection state notifying section **24**, and the command section **25** perform the operation according to this embodiment if the number of connections stored in the connection state storage section **21** is "2".

The 0-system control section **20-2** has the same structure as the 0-system control section **20-1**. The 0-system control section **20-2** controls the 0-system switch **10-2** as a control target switch.

FIG. **6** illustrates the structure of the 1-system control section **40-1**. The 1-system control section **40-1** controls the 1-system switch **30-1** as a control target switch.

A connection state storage section **41** stores data indicating the connection state among the switches and the control sections. The connection state can be updated by the state update section **43**. The connection state will be described in detail below (see FIG. **7**).

A notification receiving section **42** receives a failure detection notification from the 1-system switch **30-1**, and receives a connection state notification, a communication establishment notification, and a failure occurrence notification from the 0-system control section **20-1** in the own unit or the 1-system control section **40-2** in the opposite unit.

A state update section **43** updates the connection state of the connection state storage section **41** according to the content of the notifications. The content of the update will be described in detail below (see FIG. **18**, FIG. **22**, FIG. **26**, FIG. **28**, FIG. **30**, FIG. **32**, FIG. **34**, and FIG. **36**).

A connection state notifying section **44** notifies the 0-system control section **20-1** in the own unit and/or the 1-system control section **40-2** in the opposite unit of the connection state stored in the connection state storage section **41**. The connection state notifying section **44** can transmit the communication establishment notification and the failure occurrence notification to the 0-system control section **20-1** and/or the 1-system control section **40-2**.

A command section **45** transmits various commands to the 1-system switch **30-1**, which is a control target switch, based on the connection state stored in the connection state storage section **41**, thereby controlling the 1-system switch **30-1**. The commands will be described in detail below (FIG. **14**).

A communication establishment section **46** establishes communication between the 0-system control section **20-1** and the 1-system control section **40-2**.

The 1-system control section **40-2** has the same structure as that of the 1-system control section **40-1**. The 1-system control section **40-2** controls the 1-system switch **30-2** as a control target switch.

FIG. **7** illustrates the connection state which may be stored in the connection state storage sections **21** and **41**. Hereinafter, a control section, which is an operation subject, is referred to as an own control section. A system including the control section, which is an operation subject, is referred to as an own system, and a system other than the own system is referred to as the other system. A control section, which is provided in the same relay unit of the own control section and which is for the other system, is referred to as the other system-control section. A relay unit including the own control section is referred to as an own unit. A relay unit opposite to the own unit is referred to as an opposite unit. Two control sections included in the opposite unit are referred to as an opposite control section with respect to the own control section, and an opposite control section with respect to the other system-control section, according to the corresponding systems. A switch, which the own control section controls as a control target, is referred to as a control target switch. A switch, which the other system-control section controls as a control target, is referred to as the other system-switch. Two switches included in the opposite unit are referred to as an opposite switch with respect to the control target switch, and an opposite switch with respect to the other system-switch, according to the corresponding systems.

An "independent state" is a state in which communication can not be established between the own control section and the other system-control section in the own unit and a state in which communication can not be established between the own control section and the opposite control section. The "independent state" is the initial state of the control section.

A "perfect state" is a state in which no failure occurs in the own unit, in the opposite unit, and between the own unit and the opposite unit. In other words, in the "perfect state", the control sections can communicate with each other. In FIG. **8**, in the case of the "perfect state", the connection state is indicated by arrows.

A "failure between the units in the other system" is a state in which communication is established between the own control section and the other system-control section in the own unit and between the own control section and the opposite control section, but a failure is taking place between the other system-switch in the own unit and the opposite switch. In FIG. **9**, in the case of the "failure between the units in the other system", the connection state is indicated by arrows.

A "failure between the units in the own system" is a state in which communication is established between the own control section and the other system-control section in the own unit and between the other system-control section in the own unit and the opposite control section, but a failure is taking place between the own control section and the opposite control section. In FIG. **9**, in the case of the "failure between the units in the own system", the connection state is indicated by arrows.

A "failure in the opposite unit" is a state in which communication is established between the own control section and the other system-control section in the own unit, between the own control section and the opposite control section thereof, and between the other system-control section in the own unit and the opposite control section thereof, but communication can not be established between both control sections in the opposite unit. In FIG. **10**, in the case of the "failure in the opposite unit", the connection state is indicated by arrows.

A "failure in the own unit" is a state in which communication can not be established between the own control section and the other system-control section in the own unit, but communication is established between both control sections in the own unit and both control sections in the opposite unit. In FIG. **10**, in the case of the "failure in the own unit", the connection state is indicated by arrows.

A "double failure between the units" is a state in which communication is established between the own control section and the other system-control section in the own unit, but a failure is taking place between the control target switch and the opposite switch thereof and between the other system-switch in the own unit and the opposite switch thereof. In FIG. **11**, in the case of the "double failure between the units", the connection state is indicated by arrows.

A "simplex state" is a state in which communication is established between the own control section and the opposite control section thereof, but communication can not be established between the own control section and the other system-control section in the own unit and between both control sections in the opposite unit. In FIG. **12**, in the case of the "simplex state", the connection state is indicated by arrows.

A "failure between the units in the other system and failure in the opposite unit" is a state in which communication is established between the own control section and the other system-control section in the own unit and between the own control section and the opposite control section thereof, but communication is not established between both control sections in the opposite unit and between the other system-control section and the opposite control section thereof. In FIG. **13**, in the case of the "failure between the units in the other system and failure in the opposite unit", the connection state is indicated by arrows.

FIG. **14** illustrates a list of information items notified between the control sections. These information items are notified by the connection state notifying sections **24** and **44**.

A "connection state" is data stored in the connection state storage sections **21** and **41** and the content thereof is one of the states illustrated in FIG. **13**. The connection state is notified to the 1-system control section **40-1**, which is the other system-control section, in the relay unit **1-1**, which is the own unit, and/or the 0-system control section **20-2**, which is the opposite control section.

The "occurrence of a failure between the units" is a notification for the detection, by the control target switch, of a communication failure with the opposite switch or of a communication failure with the opposite control section. The notification is transmitted to the other system-control section in the own unit.

The "establishment of communication between the units" is a notification for the establishment of communication with the opposite control section. The notification is transmitted to the other system-control section in the own unit.

The "occurrence of a failure in the unit" is a notification for the detection, by the control target switch, of a communication failure with the other system-switch or of a communication failure with the other system-control section in the own unit. The notification is transmitted to the opposite control section.

The "establishment of communication in the unit" is a notification for the establishment of communication with the other system-control section in the own unit. The notification is transmitted to the opposite control section.

FIG. **15** illustrates a list of commands transmitted from each control section to the control target switch. The commands are issued from the command sections **25** and **45**.

"Command **1**" is a command to permit the relay of a user traffic to the other system-switch (command to permit a relay to the other system-switch).

"Command **2**" is a command to permit the relay of a user traffic to the opposite switch (command to permit a relay to the opposite switch).

"Command **3**" is a command which is notified after communication with the other system-control section is disconnected and which is also a command to prohibit the relay of user traffic to the other system-switch (command to prohibit a relay to the other system-switch).

"Command **4**" is a command which is notified after communication with the opposite control section is disconnected and which is also a command to prohibit the relay of user traffic to the opposite switch (command to prohibit a relay to the opposite switch).

"Command **5**" is a command to suppress a processing for relaying a user traffic, received from the other system-switch, to the opposite switch (relay suppression validation command).

"Command **6**" is a command to release the suppression of a processing for relaying a user traffic, received from the other system-switch, to the opposite switch (relay suppression invalidation command).

"Command **7**" is a command to delete the MAC address, whose transmission path is set to the opposite switch, from the path control table (command to delete a path to the opposite switch).

"Command **8**" is a command to delete the MAC address, whose transmission path is set to the other system-switch, from the path control table (command to delete a path to the other system-switch).

Next, an operation when the 0-system control section **20-1**, which is the own control section, establishes initial communication with the 1-system control section **40-1**, which is the other system-control section, will be described with reference to FIGS. **16** and **17**. The 0-system control section **20-1** continuously performs the flow until initial communication with the 1-system control section **40-1** is established. The description will be made assuming that each of the connection state storage section **21** of the 0-system control section **20-1** and the connection state storage section **41** of the 1-system control section **40-1** stores the "independent state" as an initial connection state. Each operation will be described using the 0-system control section **20-1** as an operation subject.

First, the communication establishment section **26** attempts to establish communication with the communication establishment section **46** of the 1-system control section **40-1** (Steps S**01** and S**101**). If the establishment of communication is failed, the flow ends.

If communication is established, the connection state notifying section **24** notifies the 1-system control section **40-1** of the connection state. The connection state notifying section **44** of the 1-system control section **40-1** notifies the 0-system control section **20-1** of the connection state (Steps S**02** and S**102**). In this case, the connection state, which the units notify each other, is an "independent state".

Then, if it is determined that communication with the 0-system control section **20-2**, which is the opposite control section, has been established (Step S**03**), the connection state notifying section **24** transmits a notification of establishment of communication in the unit, to the 0-system control section **20-2** (Step S**04**). At the present time, the connection state is the "independent state", and communication with the 0-system control section **20-2** has not been established. Therefore, the connection state notifying section **24** proceeds to Step S**05** without transmitting the notification of establishment of communication in the unit.

Then, the state update section **23** updates the connection state of the connection state storage section **21** on the basis of the connection state stored in the connection state storage section **21** and the connection state notified from the 1-system control section **40-1** (Step S**05**).

FIG. **18** illustrates a transition table of connection state when a processing for establishing of initial communication with the other system-control section is performed. A "own control section connection state" indicates the current connection state of the own control section (in this embodiment, the 0-system control section **20-1**). The "connection state of the other system-control section" indicates a connection state notified from the other system-control section (in this embodiment, the 1-system control section **40-1**). The connection states determined by the both two states are illustrated in a matrix in the transition table.

The state update section **23** updates the connection state of the connection state storage section **21** according to the transition table. Specifically, at the present time, since the current connection state of the own control section is the "independent state" and the connection state notified from the other control section is also the "independent state", the state update section **23** updates the connection state of the connection state storage section **21** to the "double failure between the units".

Then, the command section **25** performs a relay control application determining processing (Step S**06**). Next, the operation of the relay control application determining processing will be described with reference to FIG. **19**. The command section **25** determines whether or not the connection state of the connection state storage section **21** is the "perfect state" (Step S**11**). Since the current connection state is the "double failure between the units", the command section **25** ends the determining processing without issuing the relay suppression command (Step S**12**).

Then, the command section **25** transmits command **1** to permit a relay to the 1-system switch **30-1**, which is the other system-switch, to the 0-system switch **10-1**, which is the control target switch (Steps S**07** and S**104**). The 0-system switch **10-1** can relay the frames of user traffic received thereafter to the 1-system switch **30-1** in response to command 1.

Then, the command section **25** determines whether or not the connection state of the connection state storage section **21** is the "perfect state" (Step S**08**). Since the current connection state is the "double failure between the units", the command section **25** ends the determining processing without issuing command **7** to delete the MAC address (Step S**09**).

If the connection state is the "perfect state", the command section **25** issues command **7** to the 0-system switch **10-1**. In this case, the path information update section **13** of the 0-system switch **10-1** deletes the MAC address, whose transmission path is set to the opposite switch, from the path control table in response to command **7**. Then, the 0-system switch **10-1** does not relay the frame received from the 1-system switch **30-1**, which is the other system-switch, to the 0-system switch **10-2**, which is the opposite switch. The relay section **11** adds the MAC address of the frame received there-

after as an "address" to the path control table **12**, thereby setting a new frame relay destination.

Next, an operation when the 0-system control section **20-1**, which is the own control section, establishes the initial communication with the 0-system control section **20-2**, which is the opposite control section, will be described with reference to FIGS. **20** and **21**. The 0-system control section **20-1** continuously performs the flow until the initial communication with the 0-system control section **20-2** is established. The description will be made assuming that each of the connection state storage section **21** of the 0-system control section **20-1** and the connection state storage section **21** of the 0-system control section **20-2** stores the "double failure between the units" as the connection state. Each operation will be described using the 0-system control section **20-1** as an operation subject.

First, the communication establishment section **26** attempts to establish communication with the communication establishment section **26** of the 0-system control section **20-2** (Steps S**21** and S**111**). If the establishment of communication is failed, the flow ends. If communication is established, the processing proceeds to Step S**22**.

The connection state notifying section **24** determines whether or not communication with the 1-system control section **40-1**, which is the other system-control section, has been established (Step S**22**). In the current stage, since communication is established between the 0-system control section **20-1** and the 1-system control section **40-1**, the connection state notifying section **24** transmits an inter-unit communication establishment notification (a notification indicating that communication between the units has been established) to the 1-system control section **40-1** (Steps S**23** and S**112**).

The connection state notifying section **44** of the 1-system control section **40-1** also transmits the inter-unit communication establishment notification to the 0-system control section **20-1** (Step S**112**). The notification receiving section **22** receives the inter-unit communication establishment notification from the 1-system control section **40-1** (Step S**112**).

Next, the operation of the 0-system control section **20-1** as an operation subject if the inter-unit communication establishment notification is received will be described with reference to FIG. **22**. The 0-system control section **20-1** performs a routine when receiving the inter-unit communication establishment notification from the 1-system control section **40-1**, which is the other system-control section.

FIG. **23** illustrates a transition table of connection state when the inter-unit communication establishment notification is received. A "connection state before the notification is received" is a connection state before the inter-unit communication establishment notification is received. The current connection state of the 0-system control section **20-1** is the "double failure between the units". A "connection state after the notification is received" is a connection state after the inter-unit communication establishment notification is received, that is, a connection state after update.

First, the state update section **23** updates the connection state stored in the connection state storage section **21** according to the transition table illustrated in FIG. **23** (Step S**31**). Since the connection state of the connection state storage section **21** is the "double failure between the units", the state update section **23** updates the connection state to a "failure between the units in the own system" (Step S**31**).

Then, the command section **25** performs the relay control application determining processing illustrated in FIG. **19** (Step S**32**). The command section **25** determines whether or not the connection state of the connection state storage section **21** is the "perfect state" (Step S**11**). Since the current connection state is the "failure between the units in the own system", the command section **25** ends the determining processing without issuing the relay suppression command (Step S**12**).

Then, the connection state notifying section **24** notifies the 0-system control section **20-2** of the connection state (Steps S**24** and S**114**). The connection state notifying section **24** of the 0-system control section **20-2** also notifies the 0-system control section **20-1** of the connection state (Step S**114**). At that time, a connection state in which a notification is transmitted between the units is the "failure between the units in the own system".

Then, the state update section **23** updates the connection state of the connection state storage section **21** on the basis of the connection state stored in the connection state storage section **21** and the connection state notified by the 0-system control section **20-2** (Step S**25**).

FIG. **24** illustrates a transition table of connection state when a processing for establishing of initial communication with the opposite control section is performed. The state update section **23** updates the connection state of the connection state storage section **21** according to the transition table. Specifically, since the current connection state of the own control section is the "failure between the units in the own system" and the connection state notified by the other control section is also the "failure between the units in the own system", the state update section **23** updates the connection state of the connection state storage section **21** to the "perfect state" (Step S**115**).

Then, the command section **25** performs the relay control application determining processing (processing for determining a relay control application) illustrated in FIG. **19** (Steps S**26** and S**116**). The command section **25** determines whether or not the connection state of the connection state storage section **21** is the "perfect state" (Step S**11**). Since the current connection state is the "perfect state", the command section **25** issues, to the 0-system switch **10-1** which is the control target switch, relay suppression validation command **5** to suppress a relay of a specific frame received from the 1-system switch **30-1**, which is the other system-switch, to the 0-system switch **10-2**, which is the opposite switch (Steps S**12** and S**117**). The specific frame is, for example, a frame of user traffic. In response to command **5**, the 0-system switch **10-1** does not relay the specific frame received from the 1-system switch **30-1** to the 0-system switch **10-2** thereafter. For example, a port number where the specific frame is received can be used to determine whether or not the specific frame is received from the 0-system switch **10-2**.

The command section **25** issues, to the 0-system switch **10-1** which is the control target switch, command **2** to permit the relay of a general frame to the 0-system switch **10-2** which is the opposite switch (Steps S**27** and S**118**). The general frame is, for example, a unit control frame. The 0-system switch **10-1** can relay the general frame received thereafter to the 0-system switch **10-2** in response to command **2**.

Then, the command section **25** determines whether or not the connection state of the connection state storage section **21** is the "perfect state" (Step S**28**). Since the current connection state is the "perfect state", the command section **25** issues, to the 0-system switch **10-1** which is the control target switch, command **8** to delete a path to the other system-switch to delete the MAC address, whose transmission path is set to the other system-switch, from the path control table **12** (Step S**29**, S**119**).

When the connection state is the "perfect state", the above-mentioned operation prevents the 0-system switch **10-1** from

relaying a specific frame to the 0-system switch **10-2**, which is the opposite switch. The above-mentioned operation prevents frames from being looped via a ring-shaped relay path formed by the relay paths **61-1**, **61-2**, **62**, and **63**.

The above description has been made focusing on the 0-system control section **20-1** with reference to FIGS. **16** to **24**. However, as illustrated in FIGS. **17** and **22**, the 0-system control section **20-2** and the 1-system control sections **40-1** and **40-2** independently perform the same operation as the 0-system control section **20-1**.

In FIG. **25**, the relay flow of frames from the 1-system switch **30-1** when the relay of the specific frame to each switch is suppressed by the above-mentioned processing is indicated by arrows. The 1-system switch **30-1** relays, for example, the frame received from the host terminal **51-1** illustrated in FIG. **1** to the 0-system switch **10-1** and/or the 1-system switch **30-2**. In some cases, the 1-system switch **30-2** relays the frame to the 0-system switch **10-2**.

In response to the relay suppression validation command **5** from the 0-system control section **20-1**, the 0-system switch **10-1** does not relay the specific frame received from the 1-system switch **30-1**, which is the other system-switch, to the 0-system switch **10-2**, which is the opposite switch. Similarly, in response to the relay suppression validation command **5** from the 0-system control section **20-2**, the 0-system switch **10-2** does not relay the specific frame received from the 1-system switch **30-2**, which is the other system-switch, to the 0-system switch **10-1**, which is the opposite switch. When the connection state is the "perfect state", the above-mentioned operation can prevent the frame transmitted from the 1-system switch **30-1** from being looped via the relay paths **61-1**, **61-2**, **62**, and **63**. Similarly, the frame transmitted from the 1-system switch **30-2** can be prevented from being looped.

In FIG. **26**, the relay flow of the frame from the 0-system switch **10-1** when the relay of the specific frame to each switch is suppressed by the above-mentioned processing is indicated by arrows. The 0-system switch **10-1** relays, for example, the frame received from the host terminal **51-1** illustrated in FIG. **1** to the 1-system switch **30-1** and/or the 0-system switch **10-2**. In some cases, the 0-system switch **10-2** relays the frame to the 1-system switch **30-2**.

The 1-system switch **30-1** does not relay the specific frame received from the 0-system switch **10-1**, which is the other system-switch, to the 1-system switch **30-2**, which is the opposite switch, in response to the relay suppression validation command **5** from the 1-system control section **40-1**. Similarly, the 1-system switch **30-2** does not relay the specific frame received from the 1-system switch **30-2**, which is the other system-switch, to the 1-system switch **30-1**, which is the opposite switch, in response to the relay suppression validation command 5 from the 1-system control section **40-2**. If the connection state is the "perfect state", the above-mentioned operation can prevent the frame transmitted from the 0-system switch **10-1** from being looped via the relay paths **61-1**, **61-2**, **62**, and **63**. Similarly, the frame transmitted from the 0-system switch **10-2** can be prevented from being looped.

As such, the relay system **100** according to this embodiment is provided with the control sections **20-1**, **20-2**, **40-1**, and **40-2** that control the switches **10-1**, **10-2**, **30-1**, and **30-2**, respectively. These control sections notify each other of the connection states that each stores, and update their own connection states according to a predetermined transition table on the basis of the connection state that each stores and the connection states notified from the other system-control section or the opposite control sections. If the connection state is the "perfect state", that is, a state in which no failure has occurred in any of the relay paths and frames can be looped, the control target switch is prevented from relaying a specific frame to the opposite switch. This operation can prevent a frame from being looped via the relay path while retaining the redundancy of a frame relay path.

In the above-mentioned example, the processing for establishing initial communication with the other system-control section and the processing for establishing initial communication with the opposite control section are performed. However, the relay units **1-1** and **1-2** may perform the following processing.

Next, the operation of the 0-system control section **20-1** as an operation subject when an inter-unit failure is detected will be described with reference to FIG. **27**. The 0-system control section **20-1** performs the routine when an inter-unit failure detection notification has been received from the failure detecting section **14** of the 0-system switch **10-1**, which is the control target switch. The inter-unit failure detection notification is transmitted when the failure detecting section **14** has detected the occurrence of a failure in the relay path **62**.

First, the connection state notifying section **24** determines whether or not communication with the 1-system control section **40-1**, which is the other system-control section, has been established (Step S**41**). If communication has not been established, the processing proceeds to Step S**43**. If communication has been established, the connection state notifying section **24** notifies the 1-system control section **40-1** of the occurrence of an inter-unit failure (Step S**42**).

Then, the command section **25** issues, to the 0-system switch **10-1** which is the control target switch, command **4** to prohibit the relay of a specific frame to the 0-system switch **10-2** which is the opposite switch (Step S**43**). In response to the command **4**, the 0-system switch **10-1** does not relay a specific frame received thereafter to the 0-system switch **10-2**.

Then, the command section **25** determines whether or not the connection state of the connection state storage section **21** is the "perfect state" (Step S**44**). If the current connection state is not the "perfect state", the command section **25** proceeds to Step S**47** without issuing command **7** and command **6**. If the current connection state is the "perfect state", the command section **25** issues, to the 0-system switch **10-1**, command **7** to delete the MAC address, whose transmission destination is the opposite switch, from the path control table **12** (Step S**45**), and issues, to the 0-system switch **10-1**, command **6** to release the suppression of the relay of a specific packet to the 0-system switch **10-2** (Step S**46**).

Then, the state update section **23** updates the connection state of the connection state storage section **21** on the basis of the connection state stored in the connection state storage section **21** (Step S**47**). FIG. **28** illustrates a transition table of connection state when the inter-unit failure is detected. A "connection state before communication is unavailable" is the current connection state. A "connection state after communication is unavailable" is a connection state after update. For example, if the current connection state is a "simplex state", the state update section **23** updates the connection state of the connection state storage section **21** to the "independent state".

Next, the operation of the 0-system control section **20-1** as an operation subject when a failure in the own unit is detected will be described with reference to FIG. **29**. The 0-system control section **20-1** performs the routine when a notification of the detection of a failure in the own unit has been received from the failure detecting section **14** of the 0-system switch **10-1**, which is the control target switch. The notification of

the detection of a failure in a unit is transmitted when the failure detecting section **14** detects the occurrence of a failure in the relay path **61-1**.

First, the connection state notifying section **24** determines whether or not communication with the 0-system control section **20-2**, which is the opposite control section, has been established (Step S**51**). If communication has not been established, the processing proceeds to Step S**53**. If communication has been established, the connection state notifying section **24** notifies the 0-system control section **20-2** of the occurrence of a failure in the unit (Step S**52**).

Then, the command section **25** issues, to the 0-system switch **10-1** which is the control target switch, command **3** to prohibit the relay of a specific frame to the 1-system switch **30-1** which is the other system-switch (Step S**53**). In response to command **4**, the 0-system switch **10-1** does not relay the specific frame received thereafter to the 1-system switch **30-1**.

Then, the command section **25** determines whether or not the connection state of the connection state storage section **21** is the "perfect state" (Step S**54**). If the current connection state is not the "perfect state", the command section **25** proceeds to Step S**57** without issuing command **8** or command **6**. If the current connection state is the "perfect state", the command section **25** issues, to the 0-system switch **10-1**, command **8** to delete the MAC address, whose transmission destination is the other system-switch, from the path control table **12** (Step S**55**) and issues, to the 0-system switch **10-1**, command **6** to release the suppression of the relay of a specific packet to the 0-system switch **10-2** (Step S**56**).

Then, the state update section **23** updates the connection state of the connection state storage section **21** on the basis of the connection state stored in the connection state storage section **21** (Step S**57**). FIG. **30** illustrates a transition table of connection state when a failure in the unit is detected. A "connection state before communication is unavailable" is the current connection state. A "connection state after communication is unavailable" is a connection state after update. For example, if the current connection state is a "double failure between the units", the state update section **23** updates the connection state of the connection state storage section **21** to the "independent state".

Next, the operation of the 0-system control section **20-1** as an operation subject when a notification of the occurrence of an inter-unit failure is received will be described with reference to FIG. **31**. The 0-system control section **20-1** performs the routine when an inter-unit failure detection notification from the 1-system control section **40-1**, which is the other system-control section, has been received.

First, the command section **25** determines whether or not the connection state of the connection state storage section **21** is the "perfect state" (Step S**61**). If the current connection state is not the "perfect state", the command section **25** proceeds to Step S**63** without issuing a relay suppression invalidation command **6**. If the current connection state is the "perfect state", the command section **25** issues, to the 0-system switch **10-1** which is the control target switch, command **6** to invalidate the suppression of the relay of a specific frame to the 0-system switch **10-2**, which is the opposite switch (Step S**62**).

Then, the state update section **23** updates the connection state of the connection state storage section **21** on the basis of the connection state stored in the connection state storage section **21** (Step S**63**). FIG. **32** illustrates a transition table of connection state when the notification of the occurrence of an inter-unit failure is received. A "connection state before the notification is received" is the current connection state. A "connection state after the notification is received" is a connection state after update. For example, if the current connection state is an "inter-unit failure in the own system", the state update section **23** updates the connection state of the connection state storage section **21** to the "double failure between the units".

Next, the operation of the 0-system control section **20-1** as an operation subject when a notification of the occurrence of a failure in a unit is received will be described with reference to FIG. **33**. The 0-system control section **20-1** performs the routine when a notification of the detection of a failure in a unit from the 0-system control section **20-2**, which is the opposite control section, has been received.

First, the command section **25** determines whether or not the connection state of the connection state storage section **21** is the "perfect state" (Step S**71**). If the current connection state is not the "perfect state", the command section **25** proceeds to the Step S**74** without issuing a relay suppression invalidation command **6**. If the current connection state is the "perfect state", the command section **25** issues, to the 0-system switch **10-1** which is the control target switch, command **6** to invalidate the suppression of the relay of a specific frame to the 0-system switch **10-2** which is the opposite switch (Step S**72**).

Then, the command section **25** issues command **7** to the 0-system switch **10-1**. In response to command **7**, the path information update section **13** of the 0-system switch **10-1** deletes the MAC address whose transmission destination is the opposite switch with respect to the 0-system switch **10-2** which is the opposite switch, from the path control table **12**. The relay section **11** can add the MAC address of the frame which is received thereafter as an "address" to the path control table **12**, thereby setting a new frame relay destination.

Then, the state update section **23** updates the connection state of the connection state storage section **21** based on the connection state stored in the connection state storage section **21** (Step S**74**). FIG. **34** illustrates a transition table of connection state when a notification of the occurrence of a failure in a unit is received. A "connection state before the notification is received" is the current connection state. A "connection state after the notification is received" is a connection state after update. For example, if the current connection state is an "inter-unit failure in the own system", the state update section **23** updates the connection state of the connection state storage section **21** to the "simplex state".

Next, the operation of the 0-system control section **20-1** as an operation subject when a notification of the establishment of communication in the unit is received will be described with reference to FIG. **35**. The 0-system control section **20-1** performs the routine when a notification of the occurrence of a failure in the unit from the 0-system control section **20-2**, which is an opposite control section, has been received.

First, the state update section **23** updates the connection state of the connection state storage section **21** based on the connection state stored in the connection state storage section **21** (Step S**81**). FIG. **36** illustrates a transition table of connection state when a notification of the establishment of communication in the unit is received. A "connection state before the notification is received" is a current connection state. A "connection state after the notification is received" is a connection state after update. For example, if the current connection state is the "simplex state", the state update section **23** updates the connection state of the connection state storage section **21** to the "inter-unit failure in the own system".

Then, the command section **25** performs the relay control application determining processing illustrated in FIG. **19** (Step S**82**). The command section **25** determines whether or

not the connection state of the connection state storage section **21** is the "perfect state" (Step S**11**). If the current connection state is not the "perfect state", the command section **25** ends the determining processing without issuing a relay suppression command (Step S**12**). If the current connection state is the "perfect state", the command section **25** issues, to the 0-system switch **10-1** which is the control target switch, a relay suppression validation command **5** to suppress the relay of a specific frame to the 0-system switch **10-2** which is the opposite switch (Step S**12**).

Then, the command section **25** determines whether or not the connection state of the connection state storage section **21** is the "perfect state" (Step S**83**). If the current connection state is not the "perfect state", the command section **25** ends the routine without issuing command **8**. If the current connection state is the "perfect state", the command section **25** issues, to the 0-system switch **10-1** which is the control target switch, command **8** to delete the MAC address, whose transmission destination is the other system-switch, from the path control table **12** (Step S**84**).

In response to command **8**, the path information update section **13** of the 0-system switch **10-1** deletes the MAC address, whose transmission destination is the other system-switch with respect to the 0-system switch **10-1**, from the path control table **12**. The relay section **11** can add the MAC address of the frame which is received thereafter as an "address" to the path control table **12**, thereby setting a new frame relay destination.

FIGS. **22** and **23** illustrate an operation and a transition table when an inter-unit communication establishment notification is received, respectively. Each of the 0-system control section **20-2** and the 1-system control sections **40-1** and **40-2** performs the same processing as the 0-system control section **20-1**.

As described with reference to FIGS. **27** to **36**, even when a failure is detected, a failure occurrence notification is received, and communication is established, the control sections notify each other of the connection states that each stores, and update their own connection states. If the connection state is the "perfect state", each control section issues a command to suppress the relay of a frame to the opposite switch with respect to the control target switch. Even when a failure is detected, a failure occurrence notification is received, and communication is established, the above-mentioned processing can prevent frames from being looped via the relay paths **61-1**, **61-2**, **62**, and **63** while retaining the redundancy of a frame relay path.

Various patterns are considered for the operation flow of the relay units **1-1** and **1-2** when a failure is detected, a failure occurrence notification is received, and communication is established. FIGS. **37** to **56** illustrate various patterns of the operation flow of the relay units **1-1** and **1-2**. FIGS. **37** to **56** also illustrate a connection state, a failure occurrence position, and a position of recovery from failure stored in each control section. These flows are performed according to the operation of the processing routines illustrated in FIG. **22**, FIG. **23**, and FIGS. **27** to **36**. As shown in FIGS. **37** to **56**, even when various patterns of failures are detected and a failure occurrence notification is received, the relay system **100** according to this embodiment can prevent frames from being looped via the relay paths **61-1**, **61-2**, **62**, and **63** while retaining the redundancy of a frame relay path. In addition, even when communication is established, that is, a communication is recovered from failure, the relay system **100** according to this embodiment can effectively use a frame relay path while preventing frames from being looped via the relay paths **61-1**, **61-2**, **61-3**, **62**, and **63**.

<Second Embodiment>

FIG. **57** illustrates the structure of a relay system **100** according to a second embodiment of the invention. In the relay system **100** according to this embodiment, relay units **1-1**, **1-2**, and **1-3** are connected to each other in multiple stages. Next, components different from those in the first embodiment will be mainly described. A host terminal (not illustrated) is connected to each switch in the same way as that in FIG. **1**.

A connection state storage section **41** stores "3" as the number of connections. A notification receiving section **42**, a state update section **43**, a connection state notifying section **44**, and a command section **45** perform an operation according to this embodiment if the number of connections stored in the connection state storage section **41** is equal to or greater than "3". Connection priority stored in the connection state storage sections **41** of the relay units **1-1**, **1-2**, and **1-3** are, for example, "1", "2", and "3". In this case, the smaller the number is, the higher the priority is.

When a communication establishment section **46** has been established communication between the control sections in the own unit, the connection state notifying section **44** transmits a notification of the establishment of communication (hereinafter, referred to an inter-system communication validation notification) to a control section whose connection priority is higher. For example, when communication is established between the 1-system control section **40-3** and the 0-system control section **20-3**, the connection state notifying section **44** of the 1-system control section **40-3** transmits the inter-system communication validation notification to the 1-system control section **40-2**, which is an upper device.

In addition, if communication between the control sections in the own unit is not established by the communication establishment section **46** when the notification receiving section **42** has received the inter-system communication validation notification from a lower device, the connection state notifying section **44** relays the received inter-system communication validation notification to an upper device. For example, if communication between the 1-system control section **40-2** and the 0-system control section **20-2** is not established when the notification receiving section **42** of the 1-system control section **40-2** has received the inter-system communication validation notification from the 1-system control section **40-3**, which is the lower device, the connection state notifying section **44** of the 1-system control section **40-2** relays the received inter-system communication validation notification to the 1-system control section **40-1**, which is the upper device.

In addition, if communication between the control sections in the own unit has been established by the communication establishment section **46**, and the inter-system communication validation notification has not been received from the other system-control section, when the notification receiving section **42** has received the inter-system communication validation notification from the lower device, the connection state notifying section **44** relays the received inter-system communication validation notification to the other system-control section. For example, if communication between the 1-system control section **40-2** and the 0-system control section **20-2** has been established, and the inter-system communication validation notification has not been received from the 0-system control section **20-2**, when the notification receiving section **42** of the 1-system control section **40-2** has received the inter-system communication validation notification from the 1-system control section **40-3**, which is a lower device, the connection state notifying section **44** of the 1-system control section **40-2** relays the received inter-system

communication validation notification to the 0-system control section **20-2**, which is the other system-control section. If the notification receiving section **42** has received the inter-system communication validation notification from the other system-control section, the connection state notifying section **44** does not transmit the inter-system communication validation notification to the other system-control section.

If the notification receiving section **42** receives the inter-system communication validation notification from each of the lower device and the other system-control section, the command section **45** issues a relay suppression validation command **5** to a control target switch. For example, if the notification receiving section **42** of the 1-system control section **40-1** receives the inter-system communication validation notification from each of the 1-system control section **40-2**, which is a lower device, and the 0-system control section **20-1**, which is an other system-control section, the command section **45** of the 1-system control section **40-1** issues a relay suppression validation command **5** to the 1-system switch **30-1**, which is the control target switch.

A connection state storage section **21**, a notification receiving section **22**, a state update section **23**, a connection state notifying section **24**, a command section **25**, and a communication establishment section **26** perform the same operation as the connection state storage section **41**, the notification receiving section **42**, the state update section **43**, the connection state notifying section **44**, the command section **45**, and the communication establishment section **46**.

FIG. **58** illustrates a position of recovery from failure, a failure occurrence position, a relay suppression validation position, and the flow of the inter-system communication validation notification in the relay system **100**. The flow of the inter-system communication validation notification is indicated by a dashed arrow.

If communication is established between the 1-system control section **40-3** and the 0-system control section **20-3**, that is, if communication is recovered from failure, the connection state notifying section **44** of the 1-system control section **40-3** transmits the inter-system communication validation notification to the 1-system control section **40-2**, which is an upper device. Similarly, the connection state notifying section **24** of the 0-system control section **20-3** transmits the inter-system communication validation notification to the 0-system control section **20-2**, which is an upper device.

When the notification receiving section **42** has received the inter-system communication validation notification from the 1-system control section **40-3**, which is a lower device, since communication is not established between the 1-system control section **40-2** and the 0-system control section **20-2**, that is, a communication failure occurs in the relay path **61-2**, the connection state notifying section **44** of the 1-system control section **40-2** relays the received inter-system communication validation notification to the 1-system control section **40-1**, which is an upper device. Similarly, the connection state notifying section **24** of the 0-system control section **20-2** relays the inter-system communication validation notification to the 0-system control section **20-1**, which is an upper device.

When the notification receiving section **22** of the 0-system control section **20-1** has received the inter-system communication validation notification from the 0-system control section **20-2**, which is a lower device, since communication is established between the 0-system control section **20-1** and the 1-system control section **40-1** and the inter-system communication validation notification has not been received from the 1-system control section **40-1**, the connection state notifying section **24** of the 0-system control section **20-1** relays the received inter-system communication validation notification to the 1-system control section **40-1**, which is the other system-control section. Since the inter-system communication validation notification has been received from the 0-system control section **20-1**, which is the other system-control section, the connection state notifying section **44** of the 1-system control section **40-1** does not relay the received inter-system communication validation notification to the 0-system control section **20-1**.

If the notification receiving section **42** of the 1-system control section **40-1** receives the inter-system communication validation notification from each of the 1-system control section **40-2**, which is a lower device, and the 0-system control section **20-1**, which is the other system-control section, the command section **45** of the 1-system control section **40-1** issues a relay suppression validation command **5** to the 1-system switch **30-1**, which is a control target switch. Note that, since the inter-system communication validation notification is not received from the 1-system control section **40-1**, which is the other system-control section, the command section **45** of the 0-system control section **20-1** does not relay the inter-system communication validation notification received from the 0-system control section **20-1**, which is a lower device, to the 1-system control section **40-1**.

The 1-system switch **30-1** does not relay a specific frame, such as a frame of user traffic, to the 1-system switch **30-2**, which is the opposite switch, in response to command **5** from the command section **45** of the 1-system control section **40-1**.

Even if the relay units **1-1**, **1-2**, and **1-3** are connected in three stages, the above-mentioned operation can prevent frames from being looped via the relay paths **61-1**, **61-2**, **61-3**, **62**, and **63** while retaining the redundancy of a frame relay path.

Next, an operation when relay suppression is invalidated will be described.

When a failure detection notification of the detection of a communication failure between the control target switch and the opposite switch has been received from the failure detecting section **14** of the control target switch, the connection state notifying section **24** transmits the inter-system communication invalidation notification to an upper device. For example, when receiving a failure detection notification of the detection of a communication failure between the 0-system switch **10-2**, which is the control target switch, and the 1-system switch **30-2**, which is the opposite switch, has been received from the failure detecting section **14** of the 0-system switch **10-2**, the connection state notifying section **24** of the 0-system control section **20-2** transmits the inter-system communication invalidation notification to the 0-system control section **20-1**, which is the upper device.

If communication is not established between the control sections in the own unit by the communication establishment section **26** when the notification receiving section **22** has received the inter-system communication invalidation notification from the lower device, the connection state notifying section **24** relays the received inter-system communication invalidation notification to the upper device. For example, if communication is not established between the 0-system control section **20-2** and the 1-system control section **40-2** when the notification receiving section **22** of the 0-system control section **20-2** has received the inter-system communication invalidation notification from the 0-system control section **20-3**, which is a lower device, the connection state notifying section **24** of the 0-system control section **20-2** relays the received inter-system communication invalidation notification to the 0-system control section **20-1**, which is the upper device.

If communication has been established between the control sections in the own unit by the communication establishment section **26** when the notification receiving section **22** has received the inter-system communication invalidation notification from the lower device, the connection state notifying section **24** relays the received inter-system communication invalidation notification to the other system-control section. For example, if communication is established between the 0-system control section **20-2** and the 1-system control section **40-2** when the notification receiving section **22** of the 0-system control section **20-2** has received the inter-system communication invalidation notification from the 0-system control section **20-3**, which is a lower device, the connection state notifying section **24** of the 0-system control section **20-2** relays the received inter-system communication invalidation notification to the 1-system control section **40-2**, which is the other system-control section.

If the notification receiving section **42** receives the inter-system communication invalidation notification from an other system-device when command **5** has been issued to a control target switch, the command section **25** issues a relay suppression invalidation command **6** to the control target switch. For example, if the notification receiving section **42** of the 1-system control section **40-1** receives the inter-system communication invalidation notification from the 0-system control section **20-1** which is the other system-device when command **5** has been issued to the 1-system switch **30-1** which is the control target switch, the command section **25** of the 1-system control section **40-1** issues a relay suppression invalidation command **6** to the 1-system switch **30-1**.

The connection state storage section **41**, the notification receiving section **42**, the state update section **43**, the connection state notifying section **44**, the command section **45**, and the communication establishment section **46** perform the same operation as the connection state storage section **21**, the notification receiving section **22**, the state update section **23**, the connection state notifying section **24**, the command section **25**, and the communication establishment section **26**, respectively.

FIG. **59** illustrates a failure occurrence position, a relay suppression invalidation position, and the flow of the inter-system communication invalidation notification in the relay system **100**. The flow of the inter-system communication invalidation notification is indicated by a dashed arrow.

When a failure detection notification of the detection of a communication failure between the 0-system switch **10-2**, which is the control target switch, and the 1-system switch **30-2**, which is the opposite switch, has been received from the failure detecting section **14** of the 0-system switch **10-2**, the connection state notifying section **24** of the 0-system control section **20-2** transmits the inter-system communication invalidation notification to the 0-system control section **20-1**, which is an upper device.

If communication is established between the 0-system control section **20-1** and the 1-system control section **40-1** when the notification receiving section **22** of the 0-system control section **20-1** has received the inter-system communication invalidation notification from the 0-system control section **20-2**, which is a lower device, the connection state notifying section **24** of the 0-system control section **20-1** relays the received inter-system communication invalidation notification to the 1-system control section **40-1**, which is the other system-control section.

Since command **5** has been issued to the 1-system switch **30-1**, which is the control target switch, the command section **25** of the 1-system control section **40-1** issues a relay suppression invalidation command **6** to the 1-system switch **30-1** when the notification receiving section **42** of the 1-system control section **40-1** has received the inter-system communication invalidation notification from the 0-system control section **20-1**, which is the other system-device.

In response to command **6** from the command section **45** of the 1-system control section **40-1**, the 1-system switch **30-1** can relay a specific frame which is received thereafter to the 1-system switch **30-2**, which is the opposite switch.

Even if the relay units **1-1**, **1-2**, and **1-3** are connected in three stages, the above-mentioned operation makes it possible to resume the relay of a specific frame by issuing a command to invalidate the suppression of relay to a control target switch. Therefore, it is possible to effectively utilize a frame relay path while preventing frames from being looped via the relay paths **61-1**, **61-2**, **61-3**, **62**, and **63**.

In the above-described embodiment, the relay units **1-1**, **1-2**, and **1-3** are connected in three stages. However, the relay units may be connected in four or more stages. In this case, it is possible to achieve the same effect as described above. For example, FIG. **60** illustrates a frame relay flow from the 1-system switch **30-1** at the time of relay suppression of a specific frame when the relay units are connected in four stages. FIG. **61** illustrates a frame relay flow from the 0-system switch **10-1** at the time of relay suppression of a specific frame when the relay units are connected in four stages. Even if the relay units are connected in multiple stages, the relay flow makes it possible to prevent frames from being looped via relay paths while maintaining the redundancy of a frame relay path.

As described in the first and second embodiments, in the relay unit according to the invention, each control section can select and execute one of the control aspects of the relay operation of a control target switch described in the first and second embodiments according to the number of connections stored in the connection state storage section **21** or **41**. In addition, as described in the second embodiment, it is possible to select a control aspect of the relay operation according to the connection priority. For example, the inter-system communication validation notification is transmitted from a relay unit with a lower connection priority to a relay unit with a higher connection priority, and the relay unit further relays the received inter-system communication validation notification to an upper relay unit according to a failure condition.

Embodiments of the present invention are described above, but the present invention is not limited to the embodiments as will be clear to those skilled in the art.

What is claimed is:

1. A relay unit configured to cascade in multiple stages to form a LAN, comprising:

a main-system line and a sub-system line that are configured to relay a frame;

an inter-system line that connects the main-system line and the sub-system line;

a main-system switch and a sub-system switch that are connected to each other via the inter-system line, that are connected to the main-system line and the sub-system line, respectively, and that are configured to relay frames; and

control sections configured

to control a relay operation of each of the main-system switch and the sub-system switch,

to store information on a number of connections of relay units in the LAN and information on a connection priority of the relay unit to which the control sections belong, and

to select a control aspect of the relay operation of at least one of the main-system switch and the sub-system

switch according to the number of connections and the connection priority, wherein

the control sections are configured to, upon detecting that the number of connections is 2, perform a frame relay suppression control to thereby prevent the main-system switch and the sub-system switch from relaying, to the main-system line or the sub-system line, a frame that is received via the inter-system line; and

each of the control sections is configured to store connection state information on a connection state among the control sections, to update the stored connection state information based on the stored connection state information and connection state information obtained from the others of the control sections, and to perform the frame relay suppression control upon detecting that the updated connection state information corresponds to a connection state in which the control sections are permitted to communicate with one another.

2. The relay unit according to claim **1**, wherein the control section rewritably stores the information on the number of connections and the information on the connection priority.

3. A relay system, comprising:

a first relay unit having a first main-system switch and a first sub-system switch connected via a first inter-system line;

a second relay unit having a second main-system switch and a second sub-system switch connected via a second inter-system line;

a main-system line connecting the first and second main-system switches;

a sub-system line connecting the first and second sub-system switches; and

a plurality of control sections configured to respectively control the first main-system switch, the first sub-system switch, the second main-system switch and the second sub-system switch, based on information of connection states of the control sections to their respective switch, and that of connection states of the connected switches, wherein

each of the control sections is configured to store connection state information on a connection state among the control sections, to update the stored connection state information based on the stored connection state information and connection state information obtained from the others of the control sections, and, upon detecting that the updated connection state information corresponds to a connection state in which the control sections are permitted to communicate with one another, to perform a frame relay suppression control to thereby prevent the first and second main-system switches and the first and second sub-system switches from relaying, to the main-system line or the sub-system line, a frame that is received via the first or second inter-system line, and

the control sections are configured to, upon detecting that a number of connections of relay units is 2, perform the frame relay suppression control to thereby prevent the first or second main-system switch, and the first or second sub-system switch, from relaying, to the main-system line or the sub-system line, the frame that is received via the first or second inter-system line.

4. The relay system of claim **3**, wherein the information of connection states includes the number of connections between the first and second relay units, and connection priorities of the first and second relay units.

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